CONCRETE

TABLE OF CONTENTS

PREFACE

This module is one of a set developed for the Western Alliance for Quality Transportation Construction (WAQTC). WAQTC is an alliance supported by the western state Transportation Departments, along with the Federal Highway Administration (FHWA) and the Western Federal Lands Highway Division (WFLHD) of FHWA. WAQTC's charter includes the following mission.

MISSION

Provide continuously improving quality in transportation construction.

Through our partnership, we will:

- Promote an atmosphere of trust, cooperation, and communication between government agencies and with the private sector.
- Assure personnel are qualified.
- Respond to the requirements of identified needs and new technologies that impact the products that we provide.

BACKGROUND

There are two significant driving forces behind the development of the WAQTC qualification program. One, there is a trend to the use of quality control/quality assurance (QC/QA) specifications. QC/QA specifications include qualification requirements for a contractor's QC personnel and will be requiring WAQTC qualified technicians. Two, Federal regulation on materials sampling and testing (23 CFR 637, *Quality Assurance Procedures for Construction*, published in June 1995) mandates that by June 29, 2000 all testing technicians whose results are used as part of the acceptance decision shall be qualified. In addition, the regulation allows the use of contractor test results to be used as part of the acceptance decision.

OBJECTIVES

WAQTC's objectives for its Transportation Technician Qualification Program include the following:

- To provide highly skilled, knowledgeable materials sampling and testing technicians.
- To promote uniformity and consistency in testing.
- To provide reciprocity for qualified testing technicians between states.
- To create a harmonious working atmosphere between public and private employees based upon trust, open communication, and equality of qualifications.

Training and qualification of transportation technicians is required for several reasons. It will increase the knowledge of laboratory, production, and field technicians — both industry and agency personnel — and increase the number of available, qualified testers. It will reduce problems associated with test result differences. Regional qualification eliminates the issue of reciprocity between states and allows qualified QC technicians to cross state lines without having the concern or need to be requalified by a different program.

The WAQTC Executive Committee

FORWARD

This module is one of five developed for the Western Alliance for Quality Transportation Construction (WAQTC) by AGRA Earth & Environmental, Inc. (AEE). These modules were developed to satisfy the training requirements prescribed by WAQTC for technicians involved in transportation projects. The five modules cover the areas of:

- Aggregate
- Concrete
- Asphalt
- Embankment and Base
- In-place Density

The modules are based upon AASHTO test methods along with procedures developed by WAQTC. They are narrative in style, illustrated, and include step-by-step instruction. There are review questions at the end of each test procedure, which are intended to reinforce the participants' understanding and help participants prepare for the final written and performance exams. Performance exam check lists are also included. The appendices include the corresponding AASHTO and WAQTC test methods.

Each module is in loose-leaf form. This allows updated and state-specific information to be added, as necessary. It will be the technician's responsibility to stay current as changes are made to this living document.

The comments and suggestions of every participant are essential to the continued success and high standards of the Transportation Technician Qualification Program. Please take the time to fill out the Course Evaluation Form as the course progresses and hand it in on the last day of class. If you need additional room to fully convey your thoughts, please use the back of the form.

The WAQTC Executive Committee

GUIDANCE FOR COURSE EVALUATION FORM

The Course Evaluation Form on the following page is very important to the continuing improvement and success of this course. The form is included in each Participant Workbook. During the course introduction, the Instructor will call the participants' attention to the form, its content, and the importance of its thoughtful completion at the end of the course. Participants will be encouraged to keep notes, or write down comments as the class progresses, in order to provide the best possible evaluation. The Instructor will direct participants to write down comments at the end of each day and to make use of the back of the form if more room is needed for comments.

On the last day of the course, just prior to the written examination, the Instructor will again refer to the form and instruct participants that completion of the form after their last examination is a requirement prior to leaving. Should the course have more than one Instructor, participants should be directed to list them as A, B, etc., with the Instructor's name beside the letter, and direct their answers in the Instructor Evaluation portion of the form accordingly.

WESTERN ALLIANCE FOR QUALITY TRANSPORTATION CONSTRUCTION
COURSE EVALUATION FORM

The WAQTC Transportation Technician Qualification Program would appreciate your thoughtful completion of all items on this evaluation form. Your comments and constructive suggestions will be an asset in our continuing efforts to improve our course content and presentations.

Course Title: ______________________________

Location: ______________________________

Dates: ______________________________

Your Name (Optional): ______________________________

Employer: ______________________________

Instructor(s) ______________________________

COURSE CONTENT

Will the course help you perform your job better and with more understanding? Yes Maybe No

Explain: ______________________________

____

Was there an adequate balance between theory, instruction, and hands-on application? Yes Maybe No

Explain: ______________________________

____

Did the course prepare you to confidently complete both examinations? Yes Maybe No

Explain: ______________________________

____

What was the most beneficial aspect of the course? ______________________________

____

What was the least beneficial aspect of the course? ______________________________

____

GENERAL COMMENTS

General comments on the course, content, materials, presentation method, facility, registration process, etc. Include suggestions for additional Tips!

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INSTRUCTOR EVALUATION

Were the objectives of the course, and the instructional and exam approach, clearly explained? Yes Maybe No

Explain: ____

____

Was the information presented in a clear, understandable manner? Yes Maybe No

Explain: ____

____

Did the instructors demonstrate a good knowledge of the subject? Yes Maybe No

Explain: ____

____

Did the instructors create an atmosphere in which to ask questions and hold open discussion? Yes Maybe No

Explain: ____

____

COURSE OBJECTIVES AND SCHEDULE

Learning Objectives

Instructional objectives for this course include:

- Being familiar with Quality Assurance (QA) concepts
- Developing a background in measurements and calculations
- Being knowledgeable in highway materials terminology
- Respecting safety issues
- Acquiring knowledge of random sampling techniques
- Understanding the basics of concrete
- Becoming proficient in the following quality control test procedures:

  FOP for WAQTC TM 2
  Sampling Freshly Mixed Concrete

  FOP for AASHTO 309
  Test Method for Temperature of Freshly Mixed Portland Cement Concrete

  FOP for AASHTO T 119
  Slump of Hydraulic Cement Concrete

  FOP for AASHTO T 121
  Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

  FOP for AASHTO T 152
  Air Content of Freshly Mixed Concrete by the Pressure Method

  FOP for AASHTO T 23
  Making and Curing Concrete Test Specimens

The overall goals are to understand concrete and to be competent with specific quality control test procedures identified for the Transportation Technician Qualification Program (TTQP) of the Western Alliance for Quality Transportation Construction (WAQTC).

Course Outline and Suggested Schedule

Day One

0800 Welcome
Introduction of Instructors
Introduction and Expectations of Participants

0815	WAQTC Mission and TTQP Objectives Instructional Objectives for the Course Overview of the Course Course Evaluation Form
0830	Review of Quality Assurance Concepts
0845	Background in Measurements and Calculations
0945	Break
1000	Random Sampling
1015	Basics of Concrete
1045	Sampling Freshly Mixed Concrete FOP for WAQTC TM 2
1115	Temperature of Freshly Mixed Portland Cement Concrete FOP for AASHTO T 309
1130	Review Questions Questions and Answers
1200	Lunch
1315	Slump of Hydraulic Cement Concrete FOP for AASHTO T 119
1345	Review Questions Questions and Answers
1400	Laboratory Practice Temperature Slump
1645	Evaluation End of Day

Day Two

0800	Questions from the Previous Day
0815	Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete FOP for AASHTO T 121
0845	Air Content of Freshly Mixed Concrete by the Pressure Method FOP for AASHTO T 152

0915	Making and Curing Concrete Test Specimens in the Field FOP for AASHTO T 23
0945	Break
1000	Review Questions Questions and Answers
1030	Laboratory Practice Density Air Content Test Specimens
1200	Lunch
1315	Laboratory Practice Density Air Content Test Specimens
1645	Evaluation End of Day

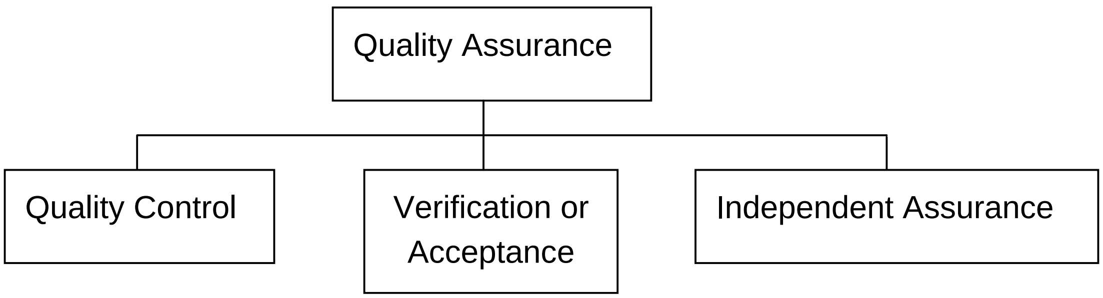
Day Three

0800	Start of Exams
	Participants will break into groups so that written and practical exams may be given concurrently.
	Evaluation

QUALITY ASSURANCE CONCEPTS

The Federal Highway Administration (FHWA) has established requirements that each 01
State Highway Agency (SHA) must develop a Quality Assurance (QA) Program that is
approved by the FHWA for projects on the National Highway System (NHS). In
addition to complying with this requirement, implementing QA specifications in a 02
construction program includes the benefit of improvement of overall quality of highway
and bridge construction.

A QA Program may include three separate and distinct parts as illustrated below.



03

Quality Assurance (QA) are those planned and systematic actions necessary to provide 04
confidence that a product or service will satisfy given requirements for quality.

Quality Control (QC) are those operational, process control techniques or activities that 05
are performed or conducted to fulfill contract requirements for material and equipment
quality. In some states, the constructor is responsible for providing QC sampling and
testing, while in other states the SHA handles QC. Where the constructor is responsible
for QC tests, the results may be used for acceptance only if verified or accepted by
additional tests performed by an independent group.

Verification/Acceptance consists of the sampling and testing performed to validate QC 06
sampling and testing and, thus, the quality of the product. Verification/Acceptance
samples are obtained and tests are performed independently from those involved with
QC. Samples taken for QC tests may not be used for Verification/Acceptance testing.

Independent Assurance (IA) are those activities that are an unbiased and independent 07
evaluation of all the sampling and testing procedures used in QC and
Verification/Acceptance. IA may use a combination of laboratory certification,
technician qualification or certification, proficiency samples, and/or split samples to
assure that QC and Verification/Acceptance activities are valid. Agencies may qualify or
certify laboratories and technicians, depending on the state in which the work is done.

CONCRETE

BACKGROUND ON MEASUREMENTS AND CALCULATIONS

01 ### Introduction

This section provides a background in the mathematical rules and procedures used in making measurements and performing calculations. Topics include:

- Units: Metric vs. English
- Mass vs. Weight
- Balances and Scales
- Rounding
- Significant Figures
- Accuracy and Precision
- Tolerance

Also included is discussion of real-world applications in which the mathematical rules and procedures may not be followed.

02 ### Units: Metric vs. English

Basic units in SI include:

Length:	meter, m
Mass:	kilogram, kg
Time:	second, s

Derived units in SI include:

Force:	Newton, N

SI units

03 The bulk of this document uses dual units. Metric units are followed by Imperial, more commonly known as English, units in parentheses. For example: 25 mm (1 in.). Exams are presented in metric or english.

Metric	English
25 mm	1 in.
1 kg	2.2 lb
1000 kg/m^3	62.4 lb/ft^3
25 MPa	3600 lb/in.^{2}

Some <u>approximate</u> conversions

04 Depending on the situation, some conversions are exact, and some are approximate. One inch is exactly 25.4 mm. If a procedure calls for measuring to the closest 1/4 in., however, 5 mm is close enough. We do not have to say 6.35 mm. That is because 1/4 in. is half way between 1/8 in. and 3/8 in. – or half way between 3.2 and 9.5 mm. Additionally, the tape measure or rule used may have 5 mm marks, but may not have 1 mm marks and certainly will not be graduated in 6 mm increments.

In SI (Le Systeme International d'Unites), the basic unit of mass is the kilogram (kg) and the basic unit of force, which includes weight, is the Newton (N). Mass in this document is given in grams (g) or kg. See the section below on "Mass vs. Weight" for further discussion of this topic.

Mass vs. Weight

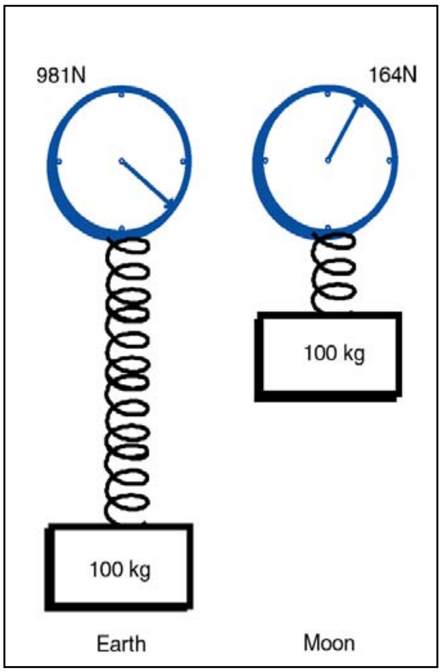
05 The terms mass, force, and weight are often confused. Mass, m, is a measure of an object’s material makeup, and has no direction. Force, F, is a measure of a push or pull, and has the direction of the push or pull. Force is equal to mass times acceleration, a.

06

$$F = ma$$

Weight, W, is a special kind of force, caused by gravitational acceleration. It is the force required to suspend or lift a mass against gravity. Weight is equal to mass times the acceleration due to gravity, g, and is directed toward the center of the earth.

$$W = mg$$



Comparison of mass and weight

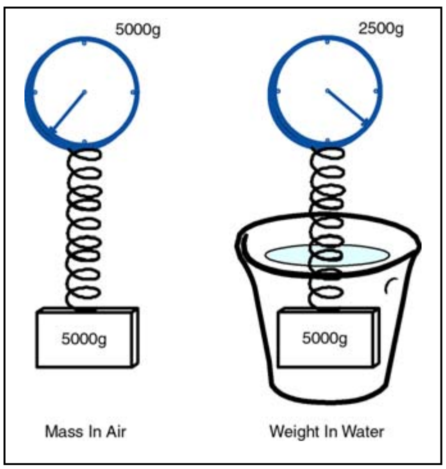
In SI, the basic unit of mass is the kilogram (kg), the units of acceleration are meters per square second (m/s^2), and the unit of force is the Newton (N). Thus a person having a mass of 84 kg subject to the standard acceleration due to gravity, on earth, of 9.81 m/s^2 would have a weight of:

$$W = (84.0 \text{ kg})(9.81 \text{ m/s}^2) = 824 \text{ kg-m/s}^2 = 824 \text{ N}$$

07 In the English system, mass can be measured in pounds-mass (lb_m), while acceleration is in feet per
08 square second (ft/s^2), and force is in pounds-force (lb_f). A person weighing 185 lb_f on a scale has a mass of 185 lb_m when subjected to the earth’s standard gravitational pull. If this person were to go to the moon, where the acceleration due to gravity is about one-sixth of what it is on earth, the person’s weight would be about 31 lb_f, while his or her mass would remain 185 lb_m. Mass does not depend on location, but weight does.

While the acceleration due to gravity does vary with position on the earth (latitude and elevation), the variation is not significant except for extremely precise work – the manufacture of electronic memory chips, for example.

As discussed above, there are two kinds of pounds, lb_m and lb_f. In laboratory measurements of mass, the gram or kilogram is the unit of choice. But, is
09 this mass or force? Technically, it depends on the instrument used, but practically speaking, mass is the result of the measurement. When using a scale, force is being measured – either electronically by the stretching of strain gauges or mechanically by the stretching of a spring or other device. When using a balance, mass is being measured, because the mass of the object is being compared to a known mass built into the balance.



Submerged weight

In this document, mass, not weight, is used in test procedures except when determining “weight” in water. When an object is submerged in water (as is done in specific gravity tests), the term weight is used. Technically, what is being measured is the force the object exerts on the balance or scale while the object is submerged in water (or the submerged weight). This force is actually the weight of the object less the weight of the volume of water displaced.

In summary, whenever the common terms “weight”
10 and “weighing” are used, the more appropriate
11 terms “mass” and “determining mass” are usually implied, except in the case of weighing an object submerged in water.

12

Balances and Scales

Balances, technically used for mass determinations, and scales, used to weigh items, were discussed briefly above in the section on “Mass vs. Weight.” In field operating procedures, we usually do not differentiate between the two types of instruments. When using either one for a material or object in air, we are determining <u>mass</u>. For those procedures in which the material or object is suspended in water, we are determining <u>weight</u> in water.

13 AASHTO recognizes two general categories of instruments. Standard analytical balances are used in laboratories. For most field operations, general purpose balances and scales are specified. Specifications for both categories are shown in
14 Tables 1 and 2.

Table 1
Standard Analytical Balances

Class	Capacity	Readability and Sensitivity	Accuracy
A	200 g	0.0001 g	0.002 g
B	200 g	0.001 g	0.002 g
C	1200 g	0.01 g	0.02 g

Table 2
General Purpose Balances and Scales

Class	Principal Sample Mass	Readability and Sensitivity	Accuracy
G2	2 kg or less	0.1 g	0.1 g or 0.1 percent
G5	2 kg to 5 kg	1 g	1 g or 0.1 percent
G20	5 kg to 20 kg	5 g	5 g or 0.1 percent
G100	Over 20 kg	20 g	20 g or 0.1 percent

15

Rounding

Numbers are commonly rounded up or down after measurement or calculation. For example, 53.67 would be rounded to 53.7 and 53.43 would be rounded to 53.4, if rounding were required. The first number was rounded up because 53.67 is closer to 53.7 than to 53.6. Likewise, the second number was rounded down because 53.43 is closer to 53.4 than to 53.5. The reasons for rounding are covered in the next section on “Significant Figures.”

If the number being rounded ends with a 5, two possibilities exist. In the more mathematically sound approach, numbers are rounded up or down depending on whether the number to the left of the 5 is odd or even. Thus, 102.25 would be rounded down to 102.2, while 102.35 would be rounded up to 102.4. This procedure avoids the bias that would exist if all numbers ending in 5 were rounded up or all numbers were rounded down. In some calculators, however, all rounding is up. This does result in some bias, or skewing of data, but the significance of the bias may or may not be significant to the calculations at hand.

Significant Figures

- General

16 A general purpose balance or scale, classified as G20 in AASHTO M 231, has a capacity of 20,000 g and an accuracy requirement of ±5 g. A mass of 18,285 g determined with such an instrument could actually range from 18,280 g to 18,290 g. Only four places in the measurement are significant. The fifth (last) place is not significant since it may change.

17 Mathematical rules exist for handling significant figures in different situations.
An example in Metric(**m**) or English(**ft**), when performing addition and subtraction, the number of significant figures in the sum or difference is determined by the least precise input. Consider the three situations shown below:

Situation 1	Situation 2	Situation 3
35.67	143.903	162
+ 423.938	- 23.6	+33.546
		- .022
= 459.61	= 120.3	= 196
not 459.608	not 120.303	not 195.524

Rules also exist for multiplication and division. These rules, and the rules for mixed operations involving addition, subtraction, multiplication, and/or division, are beyond the scope of these materials. AASHTO covers this topic to a certain extent in the section called “Precision” or “Precision and Bias” included in many test methods, and the reader is directed to those sections if more detail is desired.

18 • Real World Limitations

While the mathematical rules of significant digits have been established, they are not always followed. For example, AASHTO Method of Test T 176, *Plastic Fines in Graded Aggregates and Soils by the Use of the Sand Equivalent Test*, prescribes a method for rounding and significant digits in conflict with the mathematical rules.

In this procedure, readings and calculated values are always rounded up. A clay reading of 7.94 would be rounded to 8.0 and a sand reading of 3.21 would be rounded to 3.3. The <u>rounded</u> numbers are then used to calculate the Sand Equivalent, which is the ratio of the two numbers multiplied by 100. In this case:

$$\frac{3.3}{8.0} \times 100 = 41.250...,$$

rounded to 41.3 and reported as 42

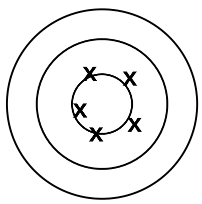
$$(\text{Not}: \frac{3.21}{7.94} \times 100 = 40.428...,$$

rounded to 40.0 and reported as 40)

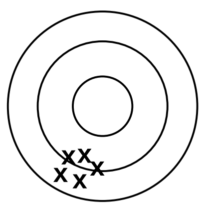
It is extremely important that engineers and technicians understand the rules of rounding and significant digits just as well as they know procedures called for in standard test methods.

Accuracy and Precision

19 Although often used interchangeably, the terms
accuracy and precision do not mean the same thing.
In an engineering sense, accuracy denotes nearness
to the truth or some value accepted as the truth,
20 while precision relates to the degree of refinement
or repeatability of a measurement.



ACCURATE BUT NOT PRECISE, SCATTERED



PRECISE BUT NOT ACCURATE, BIASED

Two bullseye targets are shown to the left. The upper one indicates hits that are scattered and, yet, are very close to the center. The lower one has a tight pattern, but all the shots are biased from the center. The upper one is more accurate, while the lower one is more precise. A biased, but precise, instrument can often be adjusted physically or mathematically to provide reliable single measurements. A scattered, but accurate, instrument can be used if enough measurements are made to provide a valid average.

Consider the measurement of the temperature of
boiling water at standard atmospheric pressure by
21 two thermometers. Five readings were taken with
each, and the values were averaged.

Thermometer No. 1	Thermometer No. 2
101.2° 214.2°	100.6° 213.1°
101.1° 214.0°	99.2° 210.6°
101.2° 214.2°	98.9° 210.0°
101.1° 214.0°	101.0° 213.8°
101.2° 214.2°	100.3° 212.5°
AVG = 101.2° 214.2°	AVG = 100.0° 212°

No. 1 shows very little fluctuation, but is off the
22 known boiling point (100°C or 212°F) by 1.2°C or
2.2°F. No. 2 has an average value equal to the
known boiling point, but shows quite a bit of
fluctuation. While it might be preferable to use
neither thermometer, thermometer No. 1 could be

employed if 1.2°C or 2.2°F were subtracted from
each measurement. Thermometer No. 2 could be
23 used if enough measurements were made to provide
a valid average.

24 Engineering and scientific instruments should be
calibrated and compared against reference standards
periodically to assure that measurements are
accurate. If such checks are not performed, the
accuracy is uncertain, no matter what the precision.
Calibration of an instrument removes fixed error,
25 leaving only random error for concern.

Tolerance

Dimensions of constructed or manufactured objects,
26 including laboratory test equipment, cannot be
specified exactly. Some tolerance must be allowed.
Thus, procedures for including tolerance in
addition/subtraction and multiplication/division
operations must be understood.

- Addition and Subtraction

  27 When adding or subtracting two numbers that individually have a tolerance, the tolerance of the sum or difference is equal to the sum of the individual tolerances.

  An example in Metric(**m**) or English(**ft**), if the distance between two points is made up of two parts, one being 113.361 ±0.006 and the other being 87.242 ±0.005 then the tolerance of the sum (or the difference) is:

  (0.006) + (0.005) = 0.011

  and the sum would be 200.603 ±0.011.

- Multiplication and Division

  28 To demonstrate the determination of tolerance again in either Metric(**m**) or English(**ft**) for the product of two numbers, consider determining the area of a rectangle having sides of 76.254

±0.009 and 34.972 ±0.007. The percentage variations of the two dimensions are:

$$\frac{0.009}{76.254} \times 100 = 0.01\% \qquad \frac{0.007}{34.972} \times 100 = 0.02\%$$

The sum of the percentage variations is 0.03 percent – the variation that is employed in the area of the rectangle:

Area =
2666.8 (m^2 or ft^2) ±0.03 percent = 2666.8 ± 0.8 (m^2 or ft^2).

- Real World Applications

29 Tolerances are used whenever a product is manufactured. For example, the mold used for determining soil density in AASHTO T 99 has a diameter of 101.60 ±0.41 mm(4.000 ±0.016 in) and a height of 116.43 ±0.13 mm(4.584 ±0.005 in).

Using the smaller of each dimension results in a volume of:

$(\pi/4)$ (101.19 mm)^2 (116.30 mm) =
935,287 mm^3 or 0.000935 m^3

$(\pi/4)$ (3.984 in)^2 (4.579 in) =
57.082in^3 or 0.0330 ft^3

Using the larger of each dimension results in a volume of:

$(\pi/4)$ (102.01 mm)^2 (116.56 mm) =
952,631 mm^3 or 0.000953 m^3

$(\pi/4)$ (4.016 in)^2 (4.589 in) =
58.130 in^3 or 0.0336 ft^3

The average value is 0.000944 m^3 (0.0333), and AASHTO T 99 specifies a volume of:

0.000943 ±0.000008 m^3
or a range of
0.000935 to 0.000951 m^3

0.0333 ±0.0003 ft^3
or a range of
0.0330 to 0.0336 ft^3

Because of the variation that can occur, some agencies periodically calibrate molds, and make adjustments to calculated density based on those calculations.

Summary

Mathematics has certain rules and procedures for making measurements and performing calculations that are well established. So are standardized test procedures. Sometimes these agree, but occasionally, they do not. Engineers and technicians must be familiar with both, but must follow test procedures in order to obtain valid, comparable results.

TERMINOLOGY

Many of the terms listed below are defined differently by various agencies or organizations. The definitions of the American Association of State Highway and Transportation Officials (AASHTO) are the ones most commonly used in this document.

Absorbed water – Water drawn into a solid by absorption, and having physical properties similar to ordinary water.

Absorption – The increase in the mass of aggregate due to water being absorbed into the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

ACC batch plant – A manufacturing facility for producing asphalt cement concrete (ACC) that proportions aggregate by weight and asphalt by weight or volume.

ACC continuous mix plant – A manufacturing facility for producing asphalt cement concrete (ACC) that proportions aggregate and asphalt by a continuous volumetric proportioning system without specific batch intervals.

Acceptance – See verification.

Acceptance program – All factors that comprise the State Highway Agency's (SHA) determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection and may include results of quality control sampling and testing.

Admixture – Material other than water, cement, and aggregates in Portland cement concrete (PCC).

Adsorbed water – Water attached to the surface of a solid by electrochemical forces, and having physical properties substantially different from ordinary water.

Aggregate – Hard granular material of mineral composition, including sand, gravel, slag or crushed stone, used in roadway base and in portland cement concrete (PCC) and asphalt cement concrete (ACC).

- **Coarse aggregate** – Aggregate retained on or above the 4.75 mm (No. 4) sieve.
- **Coarse-graded aggregate** – Aggregate having a predominance of coarse sizes.
- **Dense-graded aggregate** – Aggregate having a particle size distribution such that voids occupy a relatively small percentage of the total volume.
- **Fine aggregate** – Aggregate passing the 4.75 mm (No. 4) sieve.
- **Fine-graded aggregate** – Aggregate having a predominance of fine sizes.
- **Mineral filler** – A fine mineral product at least 70 percent of which passes a 75 µm (No. 200) sieve.

- **Open-graded gap-graded aggregate –** Aggregate having a particle size distribution such that voids occupy a relatively large percentage of the total volume.
- **Well-Graded Aggregate –** Aggregate having an even distribution of particle sizes.

Aggregate storage bins – Bins that store aggregate for feeding material to the dryer in a hot mix asphalt (HMA) plant in substantially the same proportion as required in the finished mix.

Agitation – Provision of gentle motion in portland cement concrete (PCC) sufficient to prevent segregation and loss of plasticity.

Air voids – Total volume of the small air pockets between coated aggregate particles in asphalt cement concrete (ACC); expressed as a percentage of the bulk volume of the compacted paving mixture.

Ambient temperature – Temperature of the surrounding air.

Angular aggregate – Aggregate possessing well-defined edges at the intersection of roughly planar faces.

Apparent specific gravity – The ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of water.

Asphalt – A dark brown to black cementitious material in which the predominate constituents are bitumens occurring in nature or obtained through petroleum processing. Asphalt is a constituent of most crude petroleums.

Asphalt cement – An asphalt specially prepared in quality and consistency for use in the manufacture of asphalt cement concrete (ACC).

Asphalt cement concrete (ACC) – A controlled mix of aggregate and asphalt cement.

Automatic cycling control – A control system in which the opening and closing of the weigh hopper discharge gate, the bituminous discharge valve, and the pugmill discharge gate are actuated by means of automatic mechanical or electronic devices without manual control. The system includes preset timing of dry and wet mixing cycles.

Automatic dryer control – A control system that automatically maintains the temperature of aggregates discharged from the dryer.

Automatic proportioning control – A control system in which proportions of the aggregate and asphalt fractions are controlled by means of gates or valves that are opened and closed by means of automatic mechanical or electronic devices without manual control.

Bag (of cement) – 94 lb of portland cement. (Approximately 1 ft^3 of bulk cement.)

Base – A layer of selected material constructed on top of subgrade or subbase and below the paving on a roadway.

Bias – The offset or skewing of data or information away from its true or accurate position as the result of systematic error.

Binder – Asphalt cement or modified asphalt cement that binds the aggregate particles into a dense mass.

Boulders – Rock fragment, often rounded, with an average dimension larger than 300 mm (12 in.).

Bulk specific gravity – The ratio of the mass, in air, of a volume of aggregate or compacted HMA mix (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water.

Bulk specific gravity (SSD) **–** The ratio of the mass, in air, of a volume of aggregate or compacted HMA mix, including the mass of water within the voids (but not including the voids between particles), to the mass of an equal volume of water. (See saturated surface dry.)

Cementitious Materials – cement and pozzolans used in concrete such as; Portland Cement, fly ash, silica fume, & blast-furnace slag.

Clay – Fine-grained soil that exhibits plasticity over a range of water contents, and that exhibits considerable strength when dry. Also, that portion of the soil finer than 2 µm.

Cobble – Rock fragment, often rounded, with an average dimension between 75 and 300 mm (3 and 12 in.).

Cohesionless soil – Soil with little or no strength when dry and unconfined or when submerged, such as sand.

Cohesive soil – Soil with considerable strength when dry and that has significant cohesion when unconfined or submerged.

Compaction – Densification of a soil or hot mix asphalt (HMA) by mechanical means.

Compaction curve (Proctor curve or moisture-density curve) – The curve showing the relationship between the dry unit weight or density and the water content of a soil for a given compactive effort.

Compaction test (moisture-density test) – Laboratory compaction procedure in which a soil of known water content is placed in a specified manner into a mold of given dimensions, subjected to a compactive effort of controlled magnitude, and the resulting density determined.

Compressibility – Property of a soil or rock relating to susceptibility to decrease in volume when subject to load.

Constructor – The builder of a project. The individual or entity responsible for performing and completing the construction of a project required by the contract documents. Often called a contractor, since this individual or entity contracts with the owner.

Crusher-run – The total unscreened product of a stone crusher.

Delivery tolerances – Permissible variations from the desired proportions of aggregate and asphalt cement delivered to the pugmill.

Density – The ratio of mass to volume of a substance. Usually expressed in kg/m^3.

Design professional – The designer of a project. This individual or entity may provide services relating to the planning, design, and construction of a project, possibly including materials testing and construction inspection. Sometimes called a "contractor", since this individual or entity contracts with the owner.

Dryer – An apparatus that dries aggregate and heats it to specified temperatures.

Dry mix time – The time interval between introduction of aggregate into the pugmill and the addition of asphalt cement.

Durability – The property of concrete that describes its ability to resist disintegration by weathering and traffic. Included under weathering are changes in the pavement and aggregate due to the action of water, including freezing and thawing.

Effective diameter (effective size) – D_{10}, particle diameter corresponding to 10 percent finer or passing.

Embankment – Controlled, compacted material between the subgrade and subbase or base in a roadway.

End-result specifications – Specifications that require the Constructor to take the entire responsibility for supplying a product or an item of construction. The Owner's (the highway agency's) responsibility is to either accept or reject the final product or to apply a price adjustment that is commensurate with the degree of compliance with the specifications. Sometimes called performance specifications, although considered differently in highway work. (See performance specifications.)

Field operating procedure (FOP) – Procedure used in field testing on a construction site or in a field laboratory. (Based on AASHTO or NAQTC test methods.)

Fineness modulus – A factor equal to the sum of the cumulative percentages of aggregate retained on certain sieves divided by 100; the sieves are 150, 75, 37.5, 19.0, 9.5, 4.75, 2.36, 1.18, 0.60, 0.30, and 0.15 mm. Used in the design of concrete mixes. The lower the fineness modulus, the more water/cement paste that is needed to coat the aggregate.

Fines – Portion of a soil or aggregate finer than a 75 µm (No. 200) sieve. Also silts and clays.

Free water – Water on aggregate available for reaction with hydraulic cement. Mathematically, the difference between total moisture content and absorbed moisture content.

Glacial till – Material deposited by glaciation, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water.

Gradation (grain-size distribution) – The proportions by mass of a soil or fragmented rock distributed by particle size.

Gradation analysis (grain size analysis or sieve analysis) – The process of determining grain-size distribution by separation of sieves with different size openings.

Hot aggregate storage bins – Bins that store heated and separated aggregate prior to final proportioning into the mixer.

Hot mix asphalt (HMA) – High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high quality aggregate.

Hydraulic cement – Cement that sets and hardens by chemical reaction with water.

Independent assurance – Unbiased and independent evaluation of all the sampling and testing procedures, equipment, and technicians involved with Quality Control (QC) and Verification/Acceptance.

In situ – Rock or soil in its natural formation or deposit.

Liquid limit – Water content corresponding to the boundary between the liquid and plastic states.

Loam – A mixture of sand, silt and/or clay with organic matter.

Lot – A quantity of material to be controlled. It may represent a specified mass, a specified number of truckloads, or a specified time period during production.

Manual proportioning control – A control system in which proportions of the aggregate and asphalt fractions are controlled by means of gates or valves that are opened and closed by manual means. The system may or may not include power assisted devices in the actuation of gate and valve opening and closing.

Materials and methods specifications – Also called prescriptive specifications. Specifications that direct the Constructor to use specified materials in definite proportions and specific types of equipment and methods to place the material.

Maximum size – One sieve larger than nominal maximum size.

Mesh – The square opening of a sieve.

Moisture content – The ratio, expressed as a percentage, of the mass of water in a material to the dry mass of the material.

Nominal maximum size – One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

> ***Note:*** - The first sieve to normally retain more than 10% of the material usually is the second sieve in the stack but may be the third sieve.

Nuclear gauge – Instruments used to measure in-place density, moisture content, or asphalt content through the measurement of nuclear emissions.

Optimum moisture content (optimum water content) – The water content at which a soil can be compacted to a maximum dry density by a given compactive effort.

Organic soil – Soil with a high organic content.

Owner – The organization that conceives of and eventually operates and maintains a project. A State Highway Agency (SHA) is an Owner.

Paste – Mix of water and hydraulic cement that binds aggregate in portland cement concrete (PCC).

Penetration – The consistency of a bituminous material, expressed as the distance in tenths of a millimeter (0.1 mm) that a standard needle vertically penetrates a sample of the material under specified conditions of loading, time, and temperature.

Percent compaction – The ratio of density of a soil, aggregate, or HMA mix in the field to maximum density determined by a standard compaction test, expressed as a percentage.

Performance specifications – Specifications that describe how the finished product should perform. For highways, performance is typically described in terms of changes over time in physical condition of the surface and its response to load, or in terms of the cumulative traffic required to bring the pavement to a condition defined as “failure.” Specifications containing warranty/guarantee clauses are a form of performance specifications.

Plant screens – Screens located between the dryer and hot aggregate storage bins that separate the heated aggregates by size.

Plastic limit – Water content corresponding to the boundary between the plastic and the semisolid states.

Plasticity – Property of a material to continue to deform indefinitely while sustaining a constant stress.

Plasticity index – Numerical difference between the liquid limit and the plastic limit and, thus, the range of water content over which the soil is plastic.

Portland cement – Hydraulic cement produced by pulverizing portland cement clinker.

Portland cement concrete (PCC) – A controlled mix of aggregate, portland cement, and water, and possibly other admixtures.

PCC batch plant – A manufacturing facility for producing portland cement concrete.

Prescriptive specifications – See Materials and Methods specification.

Proficiency samples – Homogeneous samples that are distributed and tested by two or more laboratories. The test results are compared to assure that the laboratories are obtaining the same results.

Pugmill – A shaft mixer designed to mix aggregate and cement.

Quality assurance – Planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality. The overall system for providing quality in a constructed project, including Quality Control (QC), Verification/Acceptance, and Independent Assurance (IA).

Quality assurance specifications – Also called QC/QA specifications. A combination of end-result (performance) specifications and materials and methods (prescriptive) specifications. The Constructor is responsible for quality control, and the Owner (highway agency) is responsible for acceptance of the product.

Quality control (QC) – Operational, process control techniques or activities that are performed or conducted to fulfill contract requirements for material or equipment quality.

Random sampling – Procedure for obtaining non-biased, representative samples.

Sand – Particles of rock passing the 4.75 mm (No. 4) sieve and retained on the 75 µm (No. 200) sieve.

Saturated surface dry (SSD) – Condition of an aggregate particle, asphalt cement concrete (ACC) or portland cement concrete (PCC) core, or other porous solid when the permeable voids are filled with water, but no water is present on exposed surfaces. (See bulk specific gravity.)

Segregation – The separation of aggregate by size resulting in a non-uniform material.

SHRP – The Strategic Highway Research Program (SHRP) established in 1987 as a five-year research program to improve the performance and durability of roads and to make those roads safe for both motorists and highway workers. SHRP research funds were partly used for the development of performance-based specifications to directly relate laboratory analysis with field performance.

Sieve – Laboratory apparatus consisting of wire mesh with square openings, usually in circular or rectangular frames.

Silt – Material passing the 75 µm (No. 200) sieve that is non-plastic or very slightly plastic, and that exhibits little or no strength when dry and unconfined. Also, that portion of the soil finer than 75 µm and coarser than 2 µm.

Slump – Measurement related to the workability of concrete.

Soil – Sediments or unconsolidated accumulations of solid particles produced by the physical and chemical disintegration or rocks, and which may or may not contain organic matter.

Specific gravity – The ratio of the mass, in air, of a volume of a material to the mass of an equal volume of water.

Stability – The ability of an asphalt cement concrete (ACC) to resist deformation from imposed loads. Stability is dependent upon internal friction, cohesion, temperature, and rate of loading.

Stratified random sampling – Procedure for obtaining non-biased, representative samples in which the established lot size is divided into equally-sized sublots.

Subbase – A layer of selected material constructed between the subgrade and the base coarse in a flexible HMA roadway, or between the subgrade and portland cement concrete (PCC) pavement in a rigid PCC roadway.

Subgrade – Natural soil prepared and compacted to support a structure or roadway pavement.

Sublot – A segment of a lot chosen to represent the total lot.

Superpave™ – Superpave™ (Superior Performing Asphalt Pavement) is a trademark of the Strategic Highway Research Program (SHRP). Superpave™ is a product of the SHRP asphalt research. The Superpave™ system incorporates performance-based asphalt materials characterization with design environmental conditions to improve performance by controlling rutting, low temperature cracking and fatigue cracking. The three major components of Superpave™ are the asphalt binder specification, the mix design and analysis system, and a computer software system.

Theoretical maximum specific gravity – The ratio of the mass of a given volume of asphalt cement concrete (ACC) with no air voids to the mass of an equal volume of water, both at a stated temperature.

Topsoil – Surface soil, usually containing organic matter.

Uniformity coefficient – C_u, a value employed to quantify how uniform or well-graded an aggregate is: $C_u = D_{60}/D_{10}$. 60 percent of the aggregate, by mass, has a diameter smaller than D_{60} and 10 percent of the aggregate, by mass, has a diameter smaller than D_{10}.

Unit weight – The ratio of weight to volume of a substance. The term "density" is more commonly used.

µm – Micro millimeter (micron) Used as measurement for sieve size.

Vendor – Supplier of project-produced material that is other than the constructor.

Verification – Process of sampling and testing performed to validate Quality Control (QC) sampling and testing and, thus, the quality of the product. Sometimes called Acceptance.

Viscosity – A measure of the resistance to flow; one method of measuring the consistency of asphalt.

- **Absolute viscosity –** A method of measuring viscosity using the "poise" as the basic measurement unit. This method is used at a temperature of 60°C, typical of hot pavement.

- **Kinematic viscosity –** A method of measuring viscosity using the stoke as the basic measurement unit. This method is used at a temperature of 135°C, typical of hot asphalt at a plant.

Void in the mineral aggregate (VMA) – The volume of inter-granular void space between aggregate particles of compacted asphalt cement concrete (ACC) that includes air and asphalt; expressed as a percentage of the bulk volume of the compacted paving mixture.

Voids filled with asphalt – The portion of the void in the mineral aggregate (VMA) that contains asphalt; expressed as a percentage of the bulk volume of mix or the VMA.

Wet mixing period – The time interval between the beginning of application of asphalt material and the opening of the mixer gate.

Zero air voids curve (saturation curve) – Curve showing the zero air voids density as a function of water content.

SAFETY

The procedures included in this manual may involve hazardous materials, operations, and equipment. The procedures do not address all of the safety issues associated with their use. It is the responsibility of the employer to assess workplace hazards and to determine whether personal protective equipment (PPE) must be used. PPE must meet applicable American National Standards Institute (ANSI) standards, and be properly used and maintained. The employer must establish appropriate safety and health practices, in compliance with applicable state and federal laws, for these procedures and associated job site hazards. Hazardous materials must be addressed in a Hazard Communication program, and Material Safety Data Sheets (MSDS) must be obtained and available to workers. Supervisors and employees should be aware of job site hazards, and comply with their employers safety and health program. The following table identifies some areas that may affect individuals performing the procedures in this manual.

Body Part Affected	Potential Hazards	PPE/Procedures That May Be Appropriate
Head	Falling or fixed overhead objects; electrical shock	Hard hat or other protective helmet
Eyes and Face	Flying objects, radiation, molten metal, chemicals	Safety glasses, goggles, face shields; prescription or filter lenses
Ears	Noise	Ear plugs, ear muffs
Respiratory System	Inhalation of dusts, chemicals; O_2 deficiency	Properly fit and used respiratory protection consistent with the hazard
Skin	Chemicals including cement; heat	Appropriate chemical or heat resistant gloves, long-sleeve shirts, coveralls
Mouth, digestive system	Ingestion of toxic materials	Disposable or washable gloves, coveralls; personal hygiene
Hands	Physical injury (pinch, cut, puncture), chemicals	Appropriate gloves for physical hazards and compatible with chemicals present
Feet	Falling, sharp objects; slippery surfaces, chemicals	Safety shoes or boots (steel toed, steel shank); traction soles; rubber boots – chemicals, wet conditions
Joints, muscles, tendons	Lifting, bending, twisting, repetitive motions	Proper training and procedures; procedure modifications
Body/Torso	Falls; Burial	Fall protection; trench sloping or shoring
Miscellaneous	Traffic	Visibility, awareness, communication; driver training, safety awareness
Whole body	Radiation	Radiation safety training

CONCRETE

RANDOM SAMPLING OF CONSTRUCTION MATERIALS

01 ## Significance

Sampling and testing are two of the most important functions in quality control (QC). Data from the tests are the tools with which the quality of product is controlled. For this reason, great care must be used in following standardized sampling and testing procedures.

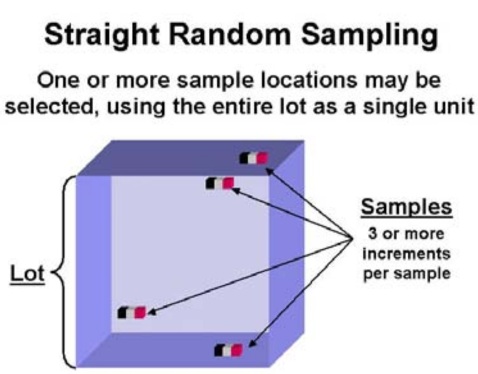
In controlling operations, it is necessary to obtain numerous samples at various points along the production line. Unless precautions are taken, sampling can occur in patterns that can create a bias to the data gathered. Sampling at the same time, say noon, each day may jeopardize the effectiveness of any quality program. This might occur, for example, because a material producer does certain operations, such as cleaning screens at an aggregate plant, late in the morning each day. To obtain a representative sample, a reliable system of random sampling must be employed.

02

Scope

The procedure presented here eliminates bias in sampling materials. Randomly selecting a set of
03 numbers from a table or calculator will eliminate
04 the possibility for bias. Random numbers are used to identify sampling times, locations, or points within a lot or sublot. This method does not cover how to sample, but rather how to determine sampling times, locations, or points.

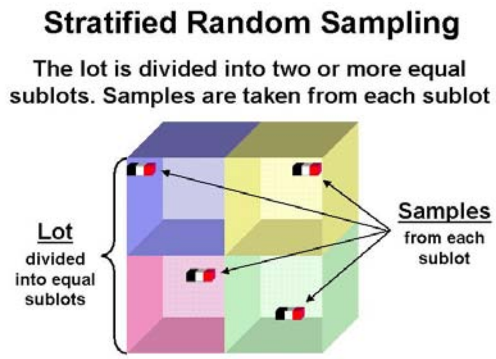
Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.



Sampling Concepts

A lot is the quantity of material evaluated by QC
05 procedures. A lot is a preselected quantity that may represent hours of production, a quantity or number of loads of material, or an interval of time. A lot may be comprised of several portions that are called sublots or units. The number of sublots comprising a lot will be determined by the

agency's specifications.



06 **Straight Random Sampling vs. Stratified Random Sampling:** Straight random sampling considers an entire lot as a single unit and determines each sample location based on the entire lot size. Stratified random sampling divides the lot into a specified number of sublots or units and then determines each sample location within a distinct sublot. Both methods result in random distribution of samples to be tested for compliance with the agency's specification.

Agencies stipulate when to use straight random sampling or stratified random sampling. AASHTO T 2, Sampling of Aggregates, for
07 example, specifies a straight random sampling procedure.

Picking Random Numbers from a Table

Table 1 contains pairs of numbers. The first
08 number is the "pick" number and the second is the Random Number, "RN". The table was generated with a spreadsheet and the cells (boxes at the intersection of rows and columns) containing the RNs actually contain the "random number function". Every time the spreadsheet is opened or changed, all the RNs change.

1. Select a Pick number in a random method. The first two or last two digits in the next automobile license plate you see would be one way to select. Another would be to start a digital stop watch and stop it several seconds later, using the decimal part of the seconds as your Pick number.
2. Find the RN matching the Pick number.

Picking Random Numbers with a Calculator

09 Many calculators have a built-in random number function. To obtain a random number, key in the code or push the button(s) the calculator's instructions call for. The display will show a number between 0.000 and 1.000 and this will be your random number.

TABLE 1
Random Numbers

Pick	RN	Pick	RN	Pick	RN	Pick	RN	Pick	RN
01	0.998	21	0.758	41	0.398	61	0.895	81	0.222
02	0.656	22	0.552	42	0.603	62	0.442	82	0.390
03	0.539	23	0.702	43	0.150	63	0.821	83	0.468
04	0.458	24	0.217	44	0.001	64	0.187	84	0.335
05	0.407	25	0.000	45	0.521	65	0.260	85	0.727
06	0.062	26	0.781	46	0.462	66	0.815	86	0.708
07	0.370	27	0.317	47	0.553	67	0.154	87	0.161
08	0.410	28	0.896	48	0.591	68	0.007	88	0.893
09	0.923	29	0.848	49	0.797	69	0.759	89	0.255
10	0.499	30	0.045	50	0.638	70	0.925	90	0.604
11	0.392	31	0.692	51	0.006	71	0.131	91	0.880
12	0.271	32	0.530	52	0.526	72	0.702	92	0.656
13	0.816	33	0.796	53	0.147	73	0.146	93	0.711
14	0.969	34	0.100	54	0.042	74	0.355	94	0.377
15	0.188	35	0.902	55	0.609	75	0.292	95	0.287
16	0.185	36	0.674	56	0.579	76	0.854	96	0.461
17	0.809	37	0.509	57	0.887	77	0.240	97	0.703
18	0.105	38	0.013	58	0.495	78	0.851	98	0.866
19	0.715	39	0.497	59	0.039	79	0.678	99	0.616
20	0.380	40	0.587	60	0.812	80	0.122	00	0.759

Examples of Straight Random Sampling Procedures Using Random Numbers

10 **Sampling from a Belt or Flowing Stream:** Agencies specify the frequency of sampling in terms of time, volumes, or masses. The specification might call for one sample from every 1,000,000 kg(1000 t) or 1100 Tons(T) of aggregate. If the random number was 0.317, the sample would be taken at (0.317)(1,000,000 kg) = 317,000 kg (317 t). Or (.317) (1100 T) = 349 T.

One sample per day might also be specified. If the day were 9 hours long and the random number 0.199, the sample would be taken at (0.199)(9 hrs) = 1.79 hr = 1 hr, 48 minutes into the day. AASHTO T 2 permits this time to be rounded to the nearest 5 minutes.

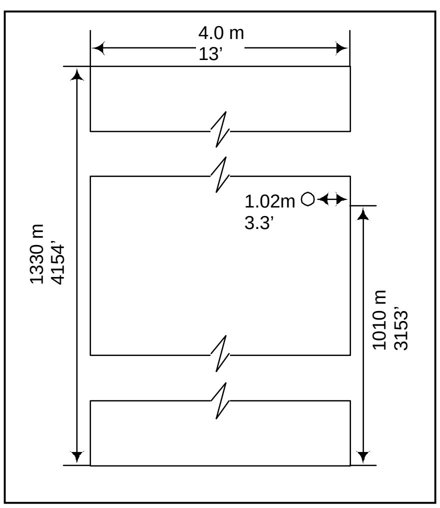
11 **Sampling from Haul Units:** Based on the agency's specifications – in terms of time, volume, or mass – determine the number of haul units that comprise a lot. Multiply the selected random number(s) by the number of units to determine which unit(s) will be sampled.

For example, if 20 haul units comprise a lot and one sample is needed, pick one RN. If the RN were 0.773, then the sample would be taken from the (0.773) (20) = 15.46, or 16th haul unit.

Sampling from a Roadway with Previously
12 **Placed Material:** The agency's specified frequency of sampling – in time, volume, or mass – can be translated into a location on a job. For example, if a sample is to be taken every 800 m^3 ($1000yd^3$) and material is being placed 0.15 m (0.50') thick and 4.0 m (13') wide, then the lot is 1330 m (4154') long. You would select two RNs in this case. To convert yd^3 to ft^3 multiply by 27.

13

The first RN would be multiplied by the length to determine where the sample would be taken along the project. The second would be multiplied by the width to determine where, widthwise, the
14 sample would be taken. For example, a first RN of 0.759 would specify that the sample would be taken at (0.759)(1330 m) or (4154') = 1010 m or 3153'from the beginning. A second RN of 0.255
15 would specify that the sample would be taken at (0.255)(4.0 m) or (13') = 1.02 m or 3.3'from the right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1') to the edge. If the RN specifies a location closer than 0.3 m (1'), then 0.3 m (1') is added to or subtracted from the distance calculated.



Sampling from a roadway

16 **Sampling from a Stockpile:** AASHTO T 2 recommends against sampling from stockpiles. However, some agencies use random procedures in determining sampling locations from a stockpile. Bear in mind that stockpiles are prone to segregation and that a sample obtained from a stockpile may not be representative. Refer to AASHTO T 2 for guidance on how to sample from a stockpile.

17 **In-Place Density Testing:** Agency specifications will indicate the frequency of tests. For example, one test per 500 m^3 (666 yd^3) might be required. If the material is being placed 0.15 m (0.50') thick and 10.0 m (33') wide, then the lot is 333 m (1090') long. You would select two RNs in this case.

18

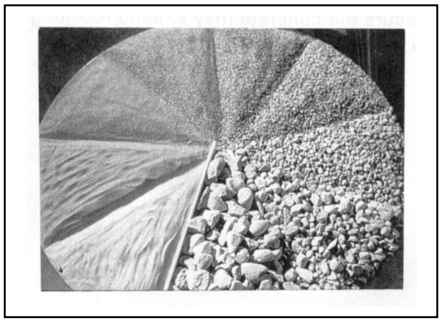
The first RN would be multiplied by the length to determine where the sample would be taken along the project. The second would be multiplied by the width to determine where, widthwise, the sample would be taken. For example, a first RN of 0.387 would specify that the sample would be taken at (0.387)(333 m) or (1090') = 129 m or (422') from the beginning. A second RN of 0.588 would specify that the sample would be taken at (0.588)(10.0 m) or (33') = 5.88 m or (19') from the
19 right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1') to the edge. If the RN specifies a location closer than 0.3 m (1'), then 0.3 m (1') is added to or subtracted from the distance calculated.

BASICS OF CONCRETE

Introduction

01 Concrete is made up of five primary constituents.

02
- Water
- Cement
- Air
- Fine Aggregate (FA)
- Coarse Aggregate (CA)

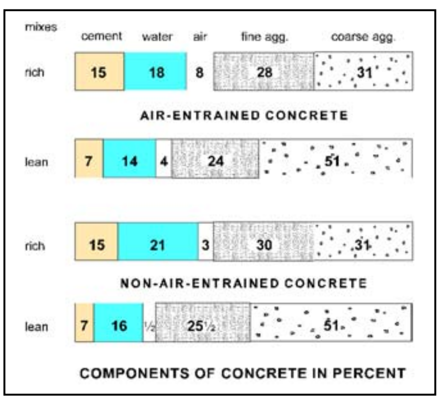


Concrete materials

03

04 The water and cement form a paste, which binds the aggregate into a rock-like mass as the water and cement combine through a chemical reaction called hydration. The paste also includes entrapped air introduced by mechanical mixing and entrained air introduced by the addition of chemical admixtures. The paste constitutes between 25 and 40 percent of the volume. The aggregates make up the remaining 60 to 75 percent. Air in concrete varies from about 1/2 to 2 percent in non-air-entrained concrete to about 4 to 8 percent in concrete containing air-entraining admixtures. When designing a mix to handle a specific environmental condition, only entrained air is counted. Entrained air is present in much smaller voids than is entrapped air.

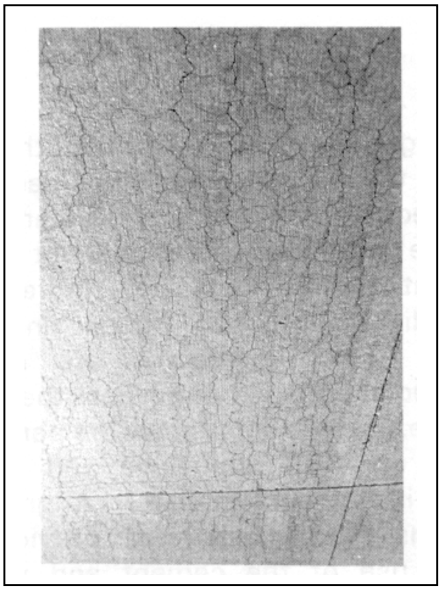
05



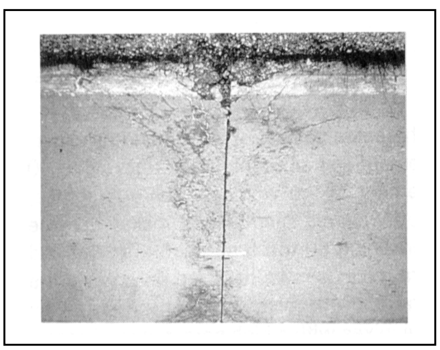
06 FA, sometimes called “sand”, is composed of particles that pass the No. 4 sieve. CA, or gravel, consists of particles retained on or above the No. 4 sieve. Well-graded aggregate, consisting of a wide range of FA and CA sizes, provides for efficient use of the water/cement paste. Since aggregate makes up most of the mix volume, it should consist of particles with adequate strength and resistance to exposure conditions.

07 Problems with concrete can be categorized in three areas:

- Unsuitable materials
- Improper construction technique
- Environmental conditions



“Map” cracking



“D” cracking

Materials selected for a concrete mix have a
tremendous impact on the quality of a project. For
08 example, poor quality aggregate raises a number of
concerns. Soft aggregates can cause pop outs in the
concrete surface. Siliceous aggregates react with the
alkali in cement, in a condition called “alkali-
aggregate reactivity”, resulting in concrete
expansion and “map” or “alligator” cracking.
Porous aggregates subject to moisture, along with
freeze-thaw cycles, will deteriorate and generate
“D-cracking”.

Water/Cement Ratio

The strength of the concrete is determined by the
water-cement ratio, that is, the ratio of the mass of
water to the mass of cement. Addition of water
above that called for in the mix design will increase
the water-cement ratio and adversely affect strength
09 and durability. Advantages of decreasing water
content include:

10
- Increased compressive and flexural strength

11
- Decreased permeability (increased watertightness)
- Lower absorption
- Increased durability (resistance to weathering)
- Better bond between successive layers
- Better bond between concrete and reinforcement
- Less bleeding
- Less volume change from wetting and drying

12
Considerations in Fresh Concrete

13

Concerns with fresh concrete include uniformity, workability, consolidation, and hydration. Fresh concrete should be plastic and capable of being

Measuring slump

molded by hand. Each aggregate particle should be coated with paste and all spaces between aggregate particles should be filled. A well-designed plastic mix keeps the components in place and does not allow segregation during transport. Plastic concrete should not crumble, but flow like a paste.

Uniformity - Fresh concrete should be uniform from batch to batch. To have a finished product that is of consistent quality throughout, each batch of plastic concrete that goes into a structure should be uniform. A commonly used measure of uniformity or consistency is slump. Factors such as water content, temperature, FA content, aggregate shape, air content, and admixtures can influence the slump of concrete. A thorough understanding of factors that can influence slump is important, and a change in slump should not be simply compensated for by varying the water content.

Workability - Concrete should not segregate or bleed water while being worked, but it must be relatively easy to place and consolidate. Transporting and placing fresh concrete as close as possible to its final location will reduce these problems and save resources.

14

Vibrating cylinder specimens

Consolidation - For concrete that cannot be consolidated manually, vibration sets the aggregate in concrete into motion and allows the mix to become mobile. This allows concrete to mold to forms and around reinforcing. Vibration permits the use of stiff mixtures with a large FA proportion. It also aids in placing concrete of high CA content. The more CA that is used, the less paste is needed since CA has less surface area per unit of mass than does FA. Less paste results in a more economical mix.

Caution must be exercised not to over-vibrate fluid mixes as segregation can occur. Conversely, under-consolidation can result in large voids or honeycombing. The size of entrapped air bubbles, which are relatively large compared with the microscopic bubbles of entrained air, can be reduced by proper vibration.

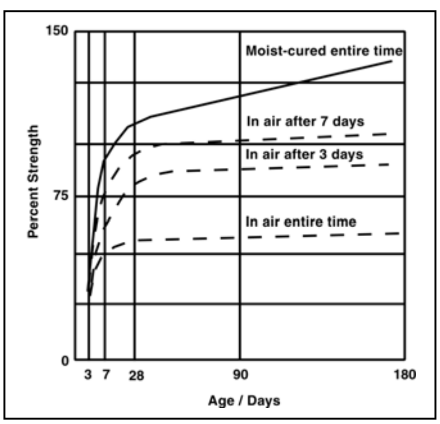
Improperly consolidated concrete

Hydration - The chemical reaction between cement and water is called hydration, and results in the
15 bonding of aggregate particles. Portland cement is an inorganic substance made up of many compounds. The anhydrous (dry) crystalline structure of cement is transformed during hydration to form calcium hydroxide (lime), calcium silicate hydrate, and other components. The concrete properties of set time and strength depend mainly upon the formation of calcium silicate hydrate. Heat is released during hydration, and the rate of the reaction is critical to the quality of the finished concrete. Depending on the chemical makeup of the cement and curing conditions, the rate of hydration and the resulting strength gain can vary significantly.

Concrete core

Strength

16 Strength is usually the primary issue in concrete mix design. Compressive strength is needed for bridges and structures, while flexural strength is needed for pavements and slabs. Concrete has little tensile strength – only about 10 percent of its compressive strength – and almost all structures are designed as though no tensile strength exists. Reinforcement provides needed tensile strength in concrete structures. Flexural strength is normally about 7.5 to 10 times the square root of the compressive strength.



Strength vs. time and curing

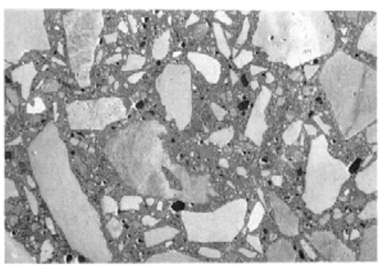
17 The principle factors affecting concrete strength are cement content, water-cement ratio, and age. Compressive strength increases as water-cement ratio decreases, and increases with age. The water and cement in concrete will continue to react as long as there is moisture available and until all the
18 anhydrous cement is consumed. It is critical to keep concrete continuously moist during curing as it will ultimately reach greater strength than concrete allowed to dry. It is important to remember that concrete does not harden by drying. When concrete dries, it ceases to gain strength. Even if it is made wet again, it will not reach the same strength as concrete kept continuously moist.

Density

Concrete that is normally used in highway work has
19 a density (sometimes called unit weight) on the
order of 145 lb/ft^3. The density test is used to determine the uniformity of concrete from batch to batch. Factors affecting concrete density include aggregate density, air content, and the water and cement content in the design – all of which are governed by the maximum aggregate size. Density of structural lightweight concrete is normally in the range of 100 to 120 lb/ft^3 and that of heavyweight concrete can run as high as 375 lb/ft^3.

20

Durability

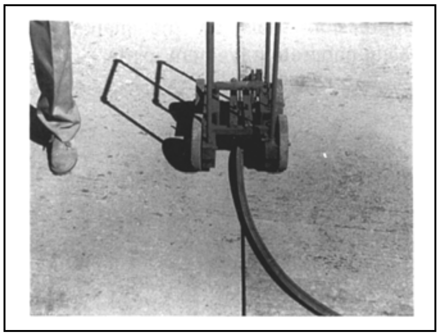


Air voids

21 Durable concrete must have high strength, be
resistant to freeze-thaw damage, have low
permeability, be abrasion resistant, and be resistant
22 to shrinking and cracking. Nondurable, saturated
concrete suffers from deterioration caused by
repeated cycles of freezing and thawing of the water
23 in the concrete paste. With air entrained concrete,
however, resistance to freeze thaw is greatly improved. A network of air bubbles provides space in which water can expand and contract as it freezes and thaws. Concrete made without air entrainment is subject to increased scaling over air entrained concrete.

Concrete exposed to severe weather conditions should have low permeability (be relatively watertight), since water can penetrate permeable concretes. If the water contains high chloride content, as does sea water, or if roads are salted, reinforcing steel can deteriorate and result in failure of the structure. The permeability of concrete depends on cement content, water-cement ratio, and the length of moist curing. The lower the water-cement ratio, the less water leakage that occurs. The longer concrete is moist cured, the more watertight the concrete will be.

24 A related durability issue is control of cracking. Cracking can be caused by applied loads, expansion and contraction, or drying shrinkage. Proper placement of joints in concrete work can reduce the amount of cracking, particularly if the joints are constructed before contraction or drying occurs. Plastic shrinkage cracks result when water evaporates from the surface of unhardened concrete. This problem is most common when concrete is placed in hot, windy, and/or low
25 humidity weather, and the concrete is not kept moist.



Control joint

Depending on the use of the concrete, abrasion resistance may also be important. Pavements can wear with age, particularly where studded tires are used. Worn pavements can be slippery if the aggregates are easily abraded. Susceptibility to abrasion is influenced by concrete strength and aggregate type.

Summary

High quality concrete requires a proper combination of materials, workmanship, and environmental conditions. The testing technician plays a critical role in helping assure that materials incorporated into a roadway meet the requirements of the proper specification. No combination of proper workmanship and environmental conditions can compensate for poor material quality.

CONCRETE

SAMPLING FRESHLY MIXED CONCRETE FOP FOR WAQTC TM 2

01 Significance

Testing fresh concrete in the field begins with obtaining and preparing the sample to be tested. Standardized procedures for obtaining a representative sample from various types of mixing and/or agitating equipment have been established. Specific time limits regarding when tests for temperature, slump, and air content must be started
02 and for when the molding of test specimens must begin are also established.

Sampling from truck mixer

Technicians must be patient and refrain from obtaining the sample too quickly. Doing so would be a violation of the specifications under which the
03 concrete is being supplied and it may result in a non-representative sample of concrete. If one considers that the specifications may require strength tests to be made only once every 100 to 150 yd^3, the need for a truly representative sample is apparent. The minimum 1 ft^3 sample from which the compressive strength test specimens will be made represents only 0.02 to 0.03 percent of the total quantity of concrete placed. For this reason, every precaution must be taken to obtain a sample that is truly representative of the entire batch and then to protect that sample from the effects of evaporation, contamination, and physical damage.

04

Scope

This method covers procedures for obtaining representative samples of fresh concrete delivered to the project site and on which tests are to be performed to determine compliance with quality requirements of the specifications under which concrete is furnished.

The method includes sampling from stationary, paving and truck mixers, and from agitating and non-agitating equipment used to transport central mixed concrete. Sampling concrete may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices.

05 **Warning—**Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

This method also covers the procedure for preparing a sample of concrete for further testing where it is necessary to remove aggregate larger than the designated size for the test method being performed. The removal of large aggregate particles is accomplished by wet sieving.

Sampling apparatus

06 Apparatus

- Wheelbarrow
- Cover for wheelbarrow (plastic, canvas, or burlap)
- Buckets
- 07 Shovel
- Cleaning equipment: including scrub brush, rubber gloves, water
- Apparatus for wet sieving including a sieve or sieves conforming to AASHTO M92 of suitable
08 size and conveniently arranged and supported so that the sieve can be shaken rapidly by hand.

09 **Procedure**

1. Use every precaution in order to obtain samples representative of the true nature and condition of the concrete being placed being careful not to obtain samples from the very first or very last portions of the batch. The size of the sample will be 1.5 times the volume of concrete required for the specified testing, but not less than 1 ft^3.

***Note 1**:* Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as at the discharge of a concrete pump.

10
- **Sampling from stationary mixers, except paving mixers**

  Sample the concrete after a minimum of 1/2 yd^3 of concrete has been discharged. Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a sample container. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and nontilting mixers.

- **Sampling from paving mixers**

  11 Sample after the contents of the paving mixer have been discharged. Obtain material from at least five different locations in the pile and combine into one test sample. Avoid contamination with subgrade material or prolonged contact with absorptive subgrade. To preclude contamination or absorption by the subgrade, the concrete may be sampled by placing a shallow container on the subgrade and discharging the concrete across the container.

12 • **Sampling from revolving drum truck mixers or agitators**

Sample the concrete after a minimum of 1/2 yd^3 of concrete has been discharged. Do not obtain samples until after all of the water has been added to the mixer. Do not obtain samples from the very first or last portions of the batch discharge. Sample by
13 repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

Open-top truck

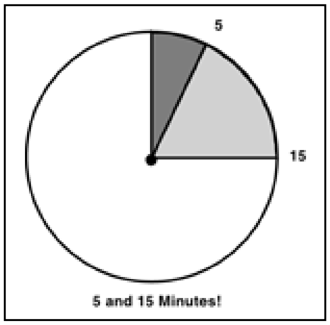
14 • **Sampling from open-top truck mixers, agitators, non-agitating equipment or other types of open-top containers**

Sample by whichever of the procedures described above is most applicable under the given conditions.

• **Sampling from pump or conveyor placement systems**

15 Sample after a minimum of 1/2 yd^3 of concrete has been discharged. Do not obtain samples until after all of the pump slurry has been eliminated. Sample by repeatedly passing a receptacle through the entire discharge system or by completely diverting the discharge into a sample container. Do not lower the pump arm from
16 the placement position to ground level for ease of sampling, as it may modify the air content of the concrete being sampled. Do not obtain samples from the very first or last portions of the batch discharge.

Sampling at pump discharge



Time from sampling to start of tests

17 2. Transport samples to the place where fresh concrete tests are to be performed and specimens are to be molded. They shall then be combined and remixed with a shovel the
18 minimum amount necessary to ensure uniformity. Protect the sample from direct sunlight, wind, rain, and sources of contamination.

3. Complete test for temperature and start tests for slump and air content within 5 minutes of
19 obtaining the sample. Complete tests as expeditiously as possible. Start molding specimens for strength tests within 15 minutes of obtaining the sample.

Wet Sieving

20 When required, due to over-size aggregate, the concrete sample shall be wet-sieved after transporting but prior to remixing for slump testing, air content testing or molding test specimens, by the following:

21
1. Place the sieve designated by the test procedure over dampened sample container.
2. Pass the concrete over the designated sieve. Do
22 not overload the sieve (one particle thick).
3. Shake or vibrate the sieve until no more material passes the sieve. A horizontal back and forth motion is preferred.
4. Discard oversize material including all adherent mortar.
5. Repeat until sample of sufficient size is obtained. Mortar adhering to the wet-sieving equipment shall be included with the sample.
6. Remix the sample with a shovel the minimum amount necessary to ensure uniformity.

Note 2: Wet-sieving is not allowed for samples being utilized for density determinations according to the FOP for AASHTO T 121.

Tips! 23

- Read the specs.
- Start tests within the time specified.
- Organize all the equipment in advance.
- Do not to obtain samples from the very first or very last portions of the batch.

REVIEW QUESTIONS

1. This method covers sampling from five types of mixers or placement systems, four of which are ______________, ______________, ________________, and _______________.

2. What is the minimum size of sample to be taken?

3. When sampling from a stationary or revolving drum truck mixer, how must the concrete be sampled during discharge of the batch?

4. The concrete sample must be protected from contamination, ________________, ________________, and ________________.

5. What time limits are specified for testing after obtaining a sample?

PERFORMANCE EXAM CHECKLIST (ORAL)

SAMPLING FRESHLY MIXED CONCRETE
FOP FOR WAQTC TM 2

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. What is the minimum sample size?		
a) 1.5 times volume of tests performed or minimum of 1 ft^3	_____	_____
2. Describe how to obtain a representative sample from a drum mixer.		
a) Sample the concrete after 1/2 yd^3 has been discharged.	_____	_____
b) Pass receptacle through entire discharge stream or completely divert discharge stream into sampling container.	_____	_____
3. Describe how to obtain a representative sample from a paving mixer.		
a) Sample the concrete after all the concrete has been discharged.	_____	_____
b) Obtain the material from at least 5 different locations in the pile.	_____	_____
c) Avoid contaminating the sample with sub grade materials.	_____	_____
4. Describe how to obtain a representative sample from a Pump:		
a) Sample the concrete after 1/2 yd^3 has been discharged.	_____	_____
b) Make sure all the pump slurry is out of the lines.	_____	_____
c) Pass receptacle through entire discharge stream or completely divert discharge stream into sampling container.	_____	_____
d) Do not stop pump or lower the pump arm from the placement position.	_____	_____
5. After obtaining the sample or samples what must you do?		
a) Transport samples to place of testing.	_____	_____
6. What must be done with the sample or samples once you have transported them to the place of testing?		
a) Combine & remix the sample.	_____	_____
b) Protect sample against rapid evaporation and contamination.	_____	_____
7. What are the two time parameters associated with this test?		
a) Complete temperature test and start tests for slump and air within 5 minutes of sample being obtained?	_____	_____
b) Start molding cylinders within 15 minutes of sample being obtained?	_____	_____
8. What test methods may require wet sieving?		
a) Slump, air content, & strength specimens?	_____	_____
9. The sieve size used for wet sieving is based on?		
a) The test method to be performed.	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
10. How long must you continue wet sieving?		
a) Until a sample of sufficient size for the test being performed is obtained.	_____	_____
11. What is done with the oversized aggregate?		
a) Discard it.	_____	_____
12. What must be done to the sieved sample before testing?		
a) Remix.	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

____

____

____

Examiner Signature _______________________________WAQTC #:_______________

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CONCRETE

WESTERN ALLIANCE FOR QUALITY
WAQTC
TRANSPORTATION CONSTRUCTION

TEMPERATURE OF FRESHLY MIXED PORTLAND CEMENT CONCRETE FOP FOR AASHTO T 309

01 Significance

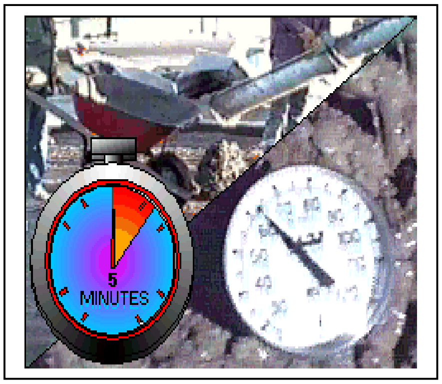
Concrete temperature is one of the most important factors influencing the quality, time of set and strength of concrete. Without control of concrete temperature, predicting the concrete's performance is very difficult, if not impossible. Concrete with a high initial temperature will probably have higher than normal early strength and lower than normal ultimate strength. Overall quality of the concrete will also probably be lowered. Conversely, concrete placed and cured at low temperatures will develop strength at a slower rate, but ultimately will have higher strength and be of a higher quality.

02 The temperatures of concrete and of the air are used
to determine the type of curing and protection that
will be needed, as well as the length of time curing
and protection should be maintained. Ideally,
concrete temperature will be between 50 and 90°F
during placement, and agency specifications may
prohibit placement when air temperature is low, say
below 36°F or high, say above 90°F. Controlling
concrete temperature and limiting placement to
certain air temperatures will reduce or eliminate
03 many problems, including those associated with
strength development and durability.

Scope

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

This procedure covers the determination of the temperature of freshly mixed portland cement concrete in accordance with AASHTO T 309.



Temperature apparatus

Apparatus

04

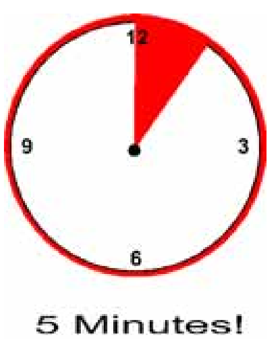
- Container — The container shall be made of nonabsorptive material and large enough to provide at least 3 in. of concrete in all directions around the sensor; concrete cover must also be a least three times the nominal maximum size of the coarse aggregate.
- Temperature Measuring Device — The temperature-measuring device shall be calibrated and capable of measuring the temperature of the freshly mixed concrete to ±1°F throughout the temperature range likely to be encountered. Partial immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.

05

- Reference Temperature Measuring Device — The reference temperature measuring device shall be a liquid-in-glass thermometer readable to 0.5°F that has been verified and calibrated. The calibration certificate or report indicating conformance to the requirements of ASTM E 77 shall be available for inspection.

Calibration of Temperature Measuring Device

Each temperature measuring device shall be verified for accuracy annually and whenever there is a question of accuracy. Calibration shall be performed by comparing readings on the temperature measuring device with another calibrated instrument at two temperatures at least 27°F apart.



Sample Locations and Times

06

The temperature of freshly mixed concrete may be measured in the transporting equipment, in forms, or in sample containers, provided the sensor of the temperature measuring device has at least 3 in. of concrete cover in all direction around it.

Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.

Concrete containing aggregate of a nominal maximum size greater than 3 in. may require up to
07 20 minutes for the transfer of heat from the aggregate to the mortar after batching.

Procedure

1. Dampen the sample container.
2. 08 Obtain the sample in accordance with the FOP for WAQTC TM 2.
3. Place sensor of the temperature measuring device in the freshly mixed concrete so that it has at least 3 in. of concrete cover in all directions around it.
4. Gently press the concrete in around the sensor of the temperature measuring device at the surface of the concrete so that air cannot reach
09 the sensor.

Pressing concrete around sensing device

5. Leave the sensor of the temperature measuring device in the freshly mixed concrete for a minimum of two minutes, or until the temperature reading stabilizes.

6. Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.
7. Read and record the temperature to the nearest 1°F.

10

Report

Results shall be reported on standard forms approved for use by the agency. Record the measured temperature of the freshly mixed concrete to the nearest 1°F.

11

Tips!

- Complete within 5 minutes of obtaining sample.
- Use calibrated temperature measuring device.
- Ensure that the sensor is surrounded by concrete, not air.
- Allow time for temperature to stabilize.

REVIEW QUESTIONS

1. Why is the temperature of concrete generally taken?

2. Summarize the specifications for the temperature measuring device.

3. The temperature measuring device shall be calibrated _________________, or whenever there is a question of _________________.

4. What special procedures are required when taking the temperature of concrete containing coarse aggregate over 3”?

5. After the temperature of the concrete is read, what is then required?

PERFORMANCE EXAM CHECKLIST

TEMPERATURE OF FRESHLY MIXED CONCRETE
FOP FOR AASHTO T 309

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Obtain sample of concrete large enough to provide a minimum of 3" of concrete cover around sensor in all directions?	_____	_____
2. Place temperature measuring device in sample with a minimum of 3" cover around sensor?	_____	_____
3. Gently press concrete around thermometer?	_____	_____
4. Read temperature after a minimum of 2 minutes or when temperature reading stabilizes?	_____	_____
5. Complete temperature measurement within 5 minutes of obtaining sample?	_____	_____
6. Record temperature to nearest 1°F?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

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Examiner Signature ______________________________WAQTC #:______________

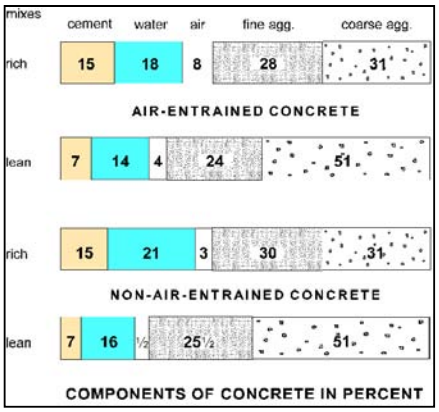
CONCRETE

WESTERN ALLIANCE FOR QUALITY
WAQTC
TRANSPORTATION CONSTRUCTION

SLUMP OF HYDRAULIC CEMENT CONCRETE
FOP FOR AASHTO T 119

01 Significance

The slump test is used to determine the consistency
02 of concrete. Consistency is a measure of the relative fluidity or mobility of the mixture. Slump does not measure the water content of the concrete. While it is true that an increase or decrease in the water content will cause a corresponding increase or decrease in the slump of the concrete, many other factors can cause slump to change without any change in water content.



03 Also, water content may increase or decrease without any change in slump. Factors such as a change in aggregate properties, grading, mix proportions, air content, concrete temperature, or the use of special admixtures can influence the slump of the concrete. These can also result in a
04 change in the water requirement for maintaining a given slump. For these reasons, one cannot assume that the water/cement ratio is being maintained simply because the slump is within the specification limits.

Scope

05 This procedure provides instructions for determining the slump of hydraulic cement concrete in accordance with AASHTO T 119. It is not applicable to non-plastic and non-cohesive concrete. With concrete using aggregate larger than 1½ in., the +1½ in. aggregate must be removed in accordance with the FOP for WAQTC TM 2.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

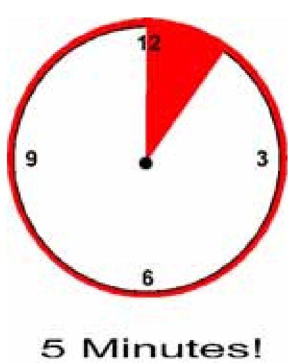
Apparatus

- Mold: The metal mold shall be provided with foot pieces and handles. The mold must be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free from dents. A mold that clamps to a rigid nonabsorbent base plate is acceptable provided the clamping arrangement is such that it can be fully released without movement of the mold.
- Mold: Other than metal must conform to AASHTO T 119 Sections 5.1.2.1 & 5.1.2.2.

06

Apparatus

- Tamping rod: 5/8 in. diameter and approximately 24 in. long, having a hemispherical tip. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Scoop
- Tape measure or ruler with at least 1/8 in. graduations
- Base: Flat, rigid, non-absorbent moistened surface on which to set the slump cone



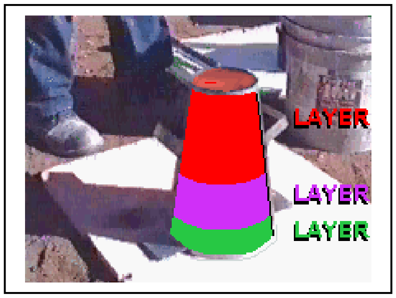
Procedure

07

1. Obtain the sample in accordance with FOP for WAQTC TM 2. If any aggregate larger than 1½ in. is present, aggregate must be removed in
08
accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

Note 1: Testing shall begin within five minutes of obtaining the sample.

2. Dampen the inside of the cone and place it on a dampened, rigid, nonabsorbent surface that is level and firm.



Three layers by volume

3. Stand on both foot pieces in order to hold the
09 mold firmly in place.
10 4. Fill the cone 1/3 full by volume, to a depth of approximately 2 5/8 in. by depth.
11 5. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. For this bottom layer, incline the rod slightly and make approximately half the strokes near the perimeter, and then progress with vertical strokes, spiraling toward the center.

Consolidating top layer

6. Fill the cone 2/3 full by volume, to a depth of approximately 6 1/8 in. by depth.
12 7. Consolidate this layer with 25 strokes of the tamping rod, just penetrating into the bottom layer. Distribute the strokes evenly.
8. Fill the cone to overflowing.
9. Consolidate this layer with 25 strokes of the tamping rod, just penetrating into the second layer. Distribute the strokes evenly. If the concrete falls below the top of the cone, stop, add more concrete, and continue rodding for a total of 25 strokes. Keep an excess of concrete above the top of the mold at all times. Distribute strokes evenly as before.

Striking off surface

13 10. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.

11. Clean overflow concrete away from the base of
14 the mold.

12. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 12 in. in 5 ±2 seconds by a steady upward
15 lift with no lateral or torsional (twisting) motion being imparted to the concrete.

The entire operation from the start of the filling through removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2 1/2 minutes. Immediately measure the slump by:

16

Lifting slump cone

Measuring slump

17 13. Invert the slump cone and set it next to the specimen.

14. Lay the tamping rod across the mold so that it is over the test specimen.

15. Measure the distance between the <u>bottom</u> of the rod and the displaced original center of the top
18 of the specimen to the nearest 1/4 in.

Note2: If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample. If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks the plasticity and cohesiveness necessary for the slump test to be applicable.

19 16. Discard the tested sample.

20

Tips!

- Start within 5 minutes of obtaining sample. 21
- Avoid locations subject to vibration.
- Consolidation strokes in middle and top layers do <u>not</u> go through entire sample.
- Fill in thirds by volume, not height.

REVIEW QUESTIONS

1. This procedure is not for all concrete. Under what concrete conditions would this procedure not be used?

2. Describe the mold used for making the slump test.

3. The surface on which the slump cone will be placed must be ____________________.

4. The approximate concrete depth (in vertical distance) after placing the first layer is _______ and the second layer is ________________.

5. When rodding the bottom layer, the tamping rod must be _____________ to uniformly distribute the strokes.

6. If, while rodding the top layer, the concrete drops below the top of the slump cone, what must be done?

7. The measurement for slump is made from the top of the mold to what point of the concrete specimen?

8. While the technician is checking the slump of the concrete, there is a decided falling away or shearing off of concrete from one side of the sample. What should the technician do?

PERFORMANCE EXAM CHECKLIST

SLUMP OF HYDRAULIC CEMENT CONCRETE
FOP FOR AASHTO T 119

Participant Name ________________________________ Exam Date _______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Cone and floor or base plate dampened?	_____	_____
2. Cone held firmly against the base by standing on the two foot pieces? Cone not allowed to move in any way during filling?	_____	_____
3. Representative samples scooped into the cone?	_____	_____
4. Cone filled in three approximately equal layers (by volume), the first to a depth of 2 5/8 in, the second to a depth of 6 1/8 in, and the third to just over the top of the cone?	_____	_____
5. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
6. Middle and top layers rodded to just penetrate into the underlying layer?	_____	_____
7. When rodding the top layer, excess concrete kept above the mold at all times?	_____	_____
8. Concrete struck off level with top of cone using tamping rod?	_____	_____
9. Concrete removed from around the outside bottom of the cone?	_____	_____
10. Cone lifted upward 12in. in one smooth motion, without a lateral or twisting motion of the cone, in 5 ±2 seconds?	_____	_____
11. Test performed from start of filling through removal of the mold within 2 1/2 minutes?	_____	_____
12. Slump immediately measured to the nearest 1/4 in. from the top of the cone to the displaced original center of the top surface of the specimen?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

____

____

Examiner Signature ________________________________WAQTC #:________________

CONCRETE

DENSITY (UNIT WEIGHT), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE

FOP FOR AASHTO T 121

01
Significance

Density, formerly called "unit weight", is a very
02 important parameter used to control the quality of
freshly mixed concrete. After a concrete mix
design has been established, a change in a
concrete's density will indicate a change in one or
more of the other concrete performance
requirements. A lower density may indicate 1) that
03 the cement or aggregate have a lower specific
gravity than expected, 2) a higher air content, 3) a
higher water content, 4) a change in the proportions
of ingredients, and/or 5) a lower cement content.
Conversely, a higher density would indicate the
reverse of the above-mentioned characteristics.

A lower density from the established concrete mix
proportion will often indicate an "over-yield",
meaning that the volume is greater than intended.
As a result, cement content per unit of volume is
lower than the mix design cement content. Lower
strength is to be expected as well as a reduction of
04 the other desirable qualities. If the reduction in
density is due to an increase in air content, the
concrete may be more durable in its resistance to
cycles of freezing and thawing, but strength,
abrasion resistance, and resistance to chemical
attack, shrinkage, and cracking will be adversely
affected. A change in density could also affect the
pumpability, placeability, and finishability. The
density test can also be used to determine the air
content of concrete, as long as the theoretical
density of the concrete computed on an air-free
basis is known.

Scope

This procedure covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121. It also provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials, and provides a method for calculating cement content & cementitious material content – the mass of cement or cementitious material per unit volume of concrete. A procedure for calculating water/cement ratio is also covered.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

Apparatus

- Measure: May be the bowl portion of the air meter used for determining air content under the FOP for AASHTO T 152. Otherwise, it shall be a metal cylindrical container meeting the requirements of AASHTO T 121. The capacity and dimensions of the measure shall conform to those specified in Table 1.
- Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use.
- Tamping Rod: 5/8 in. diameter and approximately 24 in. long, having a hemispherical tip. (Hemispherical means “half a sphere”; the tip is rounded like half of a ball.)

- 05 Glass Plate (Measure Calibration): A glass plate at least 1/4 in. thick with a length and width at least 1 in. greater than the diameter of the measure with which it is to be used.
- Vibrator: 7000 vibrations per minute, 3/4 to 1½
  06 in. diameter, and the length of the shaft shall be at least 24 in.
- Scoop
- Strike-off Plate: A flat rectangular metal plate at least 1/4 in. thick or a glass or acrylic plate at least 1/2 in. thick, with a length and width at least 2 in. greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1/16 in.
- Mallet: With a rubber or rawhide head having a mass of 1.25 ±0.5 lb for use with measures of 1/2 ft^3 or less, or having a mass of 2.25 ±0.5 lb for use with measures of 1 ft^3.

Table 1
Dimensions of Measures

Capacity	**Inside Diameter**	**Inside Height**	**Minimum Thicknesses (in.)**		**Nominal Maximum Size of Coarse Aggregate ****
(ft^3)	**(in.)**	**(in.)**	**Bottom**	**Wall**	**(in.)**
1/4	8.0 ±0.1	8.4 ±0.1	0.20	0.12	1
1/2	10.0 ±0.1	11.0 ±0.1	0.20	0.12	2
1	14.0 ±0.1	11.2 ±0.1	0.20	0.12	3

* ***Note:*** Measure may be the base of the air meter used in the FOP for AASHTO T 152.

** Nominal Maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Calibration of Measure

07 1. Determine the mass of the dry measure and glass plate.
2. Fill the measure with water at a temperature between 60°F and 85°F and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.
3. Wipe the outside of the measure and cover plate dry, being careful not to lose any water from the measure.
4. Determine the mass of the measure, glass plate, and water in the measure.
5. Determine the mass of the water in the measure by subtracting the mass in Step 1 from the mass in Step 4.
6. Measure the temperature of the water and determine its density from Table 2, interpolating as necessary.
7. Calculate the volume of the measure, V_m, by dividing the mass of the water in the measure by the density of the water at the measured temperature, from Table 2.

   Example: at 73.4°F

08

09

$$V_m = \frac{15.53\,lb}{62.274\,lb/\text{ft}^3} = 0.2494\ \text{ft}^3$$

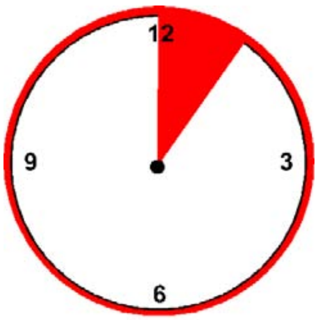
Table 2
Unit Mass of Water (15°C to 30°C)

°C	(°F)	kg/m^3	(lb/ft^3)	°C	(°F)	kg/m^3	(lb/ft^3)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Procedure Selection

10 There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 3 in., consolidation is by rodding. When the slump is 1 to 3 in., internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency in order to obtain consistent, comparable results. For slumps less than 1 in., consolidate the sample by internal vibration.

Procedure - Rodding



5 Minutes!

11 1. Obtain the sample in accordance with the FOP for WAQTC TM 2. Testing may be performed in conjunction with the FOP for AASHTO
12 T 152. When doing so, this FOP should be performed prior to the FOP for AASHTO T 152.

Note 1: If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

2. Determine the mass of the dry empty measure.
3. Dampen the inside of the measure.
4. Fill the measure approximately 1/3 full with concrete.
5. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth
13 without hitting the bottom too hard.

Consolidation

6. Tap the sides of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.
7. Add the second layer, filling the measure about 2/3 full.
14 8. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. into the bottom layer.

Tapping measure

9. Tap the sides of the measure smartly 10 to 15 times with the mallet.
10. Add the final layer, slightly overfilling the
15 measure.
11. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. into the second layer.
12. Tap the sides of the measure smartly 10 to 15 times with the mallet.

Note 2: The measure should be slightly over full, about 1/8 in. above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.

Striking off surface

13. Strike off by pressing the strike-off plate flat
16 against the top surface covering approximately
2/3 of the measure. Withdraw the strike-off
plate with a sawing motion to finish the 2/3
originally covered. Cover the original 2/3 again
with the plate; finishing the remaining 1/3 with
a sawing motion (do not lift the plate, continue
the sawing motion until the plate has cleared the
17 surface of the measure). Final finishing may be
accomplished with several strokes with the
inclined edge of the strike-off plate. The
18 surface should be smooth and free of voids.

19 14. Clean off all excess concrete from the exterior of the measure including the rim.

15. Determine and record the mass of the measure and the concrete to the nearest 0.3%.

16. If the air content of the concrete is to be determined, proceed to Rodding Procedure Step 13 of the FOP for AASHTO T 152.

20 **Procedure - Internal Vibration**

1. Perform Steps 1 through 3 of the rodding procedure.
2. Fill the measure approximately half full.
3. Insert the vibrator at four different points in each layer when a 1 ft^3 measure is used, and three different points in each layer when a 1/2 ft^3, or smaller, measure is used. Do not let the vibrator touch the bottom or sides of the measure.

Note 3: Remove the vibrator slowly, so that no air pockets are left in the material.

Note 4: Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

21 4. Fill the measure a bit over full.
5. Insert the vibrator as in Step 3. Do not let the vibrator touch the sides of the measure, and penetrate the first layer approximately 25 mm (1 in.).

6. Return to Step 13 of the rodding procedure and continue.

Calculations

- **Density –** Calculate the net mass, M_m, of the concrete in the measure by subtracting the mass of the measure from the gross mass of the measure plus the concrete. Calculate the density, W, by dividing the net mass, M_m, by the volume, V_m, of the measure as shown below.

$$W = \frac{M_m}{V_m} \qquad \text{Example:} \qquad W = \frac{36.06\ lb}{0.2494\ ft^3} = 144.6\ lb/ft^3$$ 22

- **Yield –** Calculate the yield, Y, or volume of concrete produced per batch, by dividing the total mass of the batch, W_1, by the density , W, of the concrete as shown below.

$$Y = \frac{W_1}{W} \qquad \text{Example:} \qquad Y = \frac{3978\ lb}{(27)\ (144.6\ lb/ft^3)} = 1.02\ yd^3$$ 23

Note 5: The total mass, W_1, includes the masses of the cement, water, and aggregates in the concrete.

- **Cement Content** – Calculate the actual cement content, N, by dividing the mass of the cement, N_t, by the yield, Y, as shown below.

  Note 6: Specifications may require Portland cement content and cementitious materials content. 24, 25

$$N = \frac{N_t}{Y} \qquad \text{Example:} \qquad N = \frac{602\,\text{lb}}{1.02\,\text{yd}^3} = 590\,\text{lb/yd}^3$$

- **Water Content** – Calculate the mass of water in a batch of concrete by summing the:
  - water added at batch plant
  - water added in transit
  - water added at jobsite
  - free water on coarse aggregate
  - free water on fine aggregate
  - liquid admixtures (if the agency requires this to be included).

This information is obtained from concrete batch tickets collected from the driver. Use the following conversion factors.

To Convert From	To	Multiply By
Liters, L	Kilograms, kg	1.0
Gallons, gal	Kilograms, kg	3.785
Gallons, gal	Pounds, lb	8.34
Milliliters, mL	Kilograms, kg	0.001
Ounces, oz	Milliliters, mL	28.4
Ounces, oz	Kilograms, kg	0.0284
Ounces, oz	Pounds, lb	0.0625
Pounds, lb	Kilograms, kg	0.4536

Calculate the mass of free water on aggregate as follows.

$$\text{Free Water Mass} = \text{Total Aggregate Mass} - \frac{\text{Total Aggregate Mass}}{1 + (\text{Free Water Percentage}/100)}$$

Example:

Total Aggregate Mass = 7804 lb

Free Water Percentage = 1.7 *

* To determine Free Water percentage:

Total moisture content of the aggregates – absorbed moisture = Free Water

$$\text{FreeWaterMass} = 7804\,\text{lb} - \frac{7804\,\text{lb}}{1 + (1.7/100)} = 130\,\text{lb}$$

Example for actual water content: 26

Water added at batch plant	=	79 gal	
Water added in transit	=	0 gal	
Water added at jobsite	=	<u>11 gal</u>	
		90 gal =	751 lbs

Coarse aggregate: 7804 lb @ 1.7% free water
Fine aggregate: 5489 lb @ 5.9% free water

CA free water = $7804\,\text{lb} - \dfrac{7804\,\text{lb}}{1 + (1.7/100)} = 130$ lbs

FA free water = $5489\,\text{lb} - \dfrac{5489\,\text{lb}}{1 + (5.9/100)} = 306$ lbs 27, 28

Mass of water in batch = 1187 lbs

- **Water/Cement Ratio –** Calculate the water/cement ratio by dividing the mass of water in a batch of concrete by the mass cementitious material in the batch. The masses of the cementitious materials are obtained from concrete batch tickets collected from the driver.

  Example:

Cement:	2094 lbs
Fly Ash:	397 lbs
Water:	1187 lbs (from previous example)

$$W/C = \frac{1187\,\text{lb}}{(2094 + 397\,\text{lb})} = 0.48$$

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Report

Results shall be reported on standard forms approved for use by the agency and should include the following:

- Density (unit weight) to 0.1 lb/ft^3
- Yield to 0.01 yd^3
- Cement content to 1 lb/yd^3
- Cementitious material to 1 lb/yd^3
- Water/Cement ratio to 0.01

31

Tips!

- Start within 5 minutes of obtaining sample if done along with AASHTO T 152.
- Consolidation technique depends on slump. Rodding and/or vibration may be appropriate for different slumps.
- Use a calibrated measure.

REVIEW QUESTIONS

1. What is the required shape of the tamping end of the rod?

2. What is the minimum thickness of a metal strike off plate?

3. What is the minimum thickness for a glass or acrylic strike-off plate?

4. What is the specified mass of the mallet used on measures having a volume of 1 ft^3?

5. Air meter bases used for this test must conform to what test method?

6. If, after consolidation of the final layer, the concrete level is 1/2 in. above the top of the measure, what should be done?

7. After completing the strike-off procedure, what must be done before determining the mass of the measure and sample?

PERFORMANCE EXAM CHECKLIST

DENSITY (UNIT WEIGHT), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
FOP FOR AASHTO T 121

Participant Name ______________________________ Exam Date ______________

Record the symbols “P” for passing or “F” for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Mass and volume of empty measure determined?	_____	_____
2. Dampened measure filled in three equal layers, slightly overfilling the last layer?	_____	_____
3. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
4. Bottom layer rodded throughout its depth, without forcibly striking the bottom of the measure?	_____	_____
5. Middle and top layers rodded, each throughout their depths and penetrating the previous layer by approximately 1 in. into the underlying layer?	_____	_____
6. Sides of the measure tapped 10 to 15 times with the mallet after rodding each layer?	_____	_____
7. Any excess concrete removed using a trowel or a scoop, or small quantity of concrete added to correct a deficiency, after consolidation of final layer?	_____	_____
8. Strike-off plate placed flat on the measure covering approximately 2/3 of the surface sawing action used to withdraw the strike-off plate across the previously covered surface?	_____	_____
9. Strike-off plate placed flat on the measure covering approximately 2/3 of the surface then sawing action used to advance the plate across the entire measure surface.	_____	_____
10. Strike off completed using the inclined edge of the plate creating a smooth surface?	_____	_____
11. All excess concrete cleaned off and mass of full measure determined?	_____	_____
12. Net mass calculated?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
13. Density calculated correctly ?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

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____

Examiner Signature _______________________________WAQTC #:_______________

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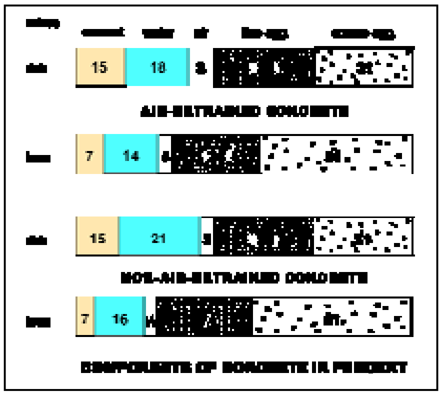
CONCRETE

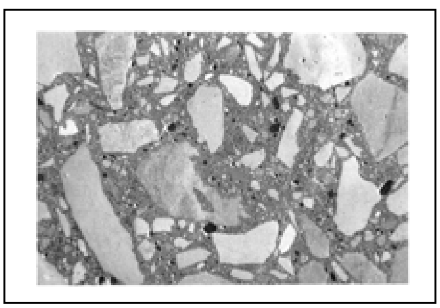
AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

01 ## Significance

Concrete is not a solid, but rather a solid with void
spaces. The voids may contain gas such as air, or
02 liquid, such as water. All concrete contains air
voids, and the amount can be increased by the
addition of an air-entraining agent to the mix.
When such an agent is used, the size of the voids
drastically decreases and the number of voids
greatly increases, providing a much greater
dispersal of voids.



Air entrainment is necessary in concrete that will be
saturated and exposed to cycles of freezing and
03 thawing, and to deicing chemicals. The
microscopic entrained air voids provide a site for
relief of internal pressure that develops as water
freezes and thaws inside the concrete. Without the
04 proper entrained-air content, normal concrete that is
saturated and is exposed to cycles of freezing and
thawing can fail prematurely by scaling, spalling, or
cracking.



Air Voids

Care must be taken, however, not to have too much
entrained air. As the air content increases, there
05 will be a corresponding reduction in the strength
and other desirable properties of the concrete.
Typically, this strength reduction will be on the
06 order of 3 to 5 percent for each 1 percent of air
content. A concrete mix design proportioned for 5
percent air, for example, will be approximately 15
to 25 percent lower in strength if the air content
were to double.

Scope

This procedure covers determination of the air
content in freshly mixed Portland Cement Concrete
containing dense aggregates in accordance with
AASHTO T 152, Type B meter. It is not for use
07 with lightweight or highly porous aggregates. This
procedure includes calibration of the Type B air
meter gauge, and two methods for calibrating the
gauge are presented. Concrete containing aggregate
that is 1 ½” or larger must be wet sieved. Sieve a
sufficient amount of the sample over the 1 ½” sieve
in accordance with the wet sieving portion of the

FOP for WAQTC TM 2.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

Apparatus

08

- Air meter: Type B, as described in AASHTO T 152.
- Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use (for Method 1 calibration only).
- Tamping rod: 5/8 in. diameter and approximately 24 in. long, having a hemispherical tip. (Hemispherical means half a sphere; the tip is rounded like half of a ball.)
- Vibrator: 7000 vibrations per minute, 0.75 to 1.50 in. in diameter, at least 3 in. longer than the section being vibrated for use with low slump concrete.
- Scoop
- Container for water: rubber syringe (may also be a squeeze bottle).
- Strike-off bar: Approximately 12 in. x 3/4 in. x 1/8 in.
- Strike-off Plate: A flat rectangular metal plate at least 1/4 in. thick or a glass or acrylic plate at least 1/2 in. thick, with a length and width at least 2 in. greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1/16 in.

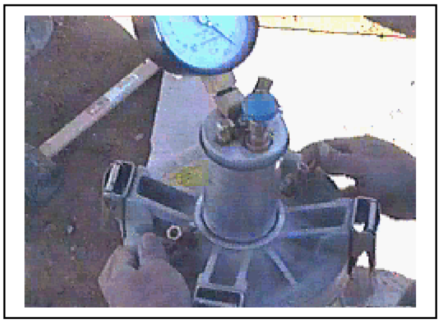
Note 1: Use either the strike-off bar or strike-off plate; both are not required.

Mallet: With a rubber or rawhide head having a mass of 1.25 ±0.5 lb.

Calibration of Air Meter Gauge

09 ***Note 2:*** There are two methods for calibrating the air meter, mass or volume.

1. Screw the short piece of straight tubing into the
10 threaded petcock hole on the underside of the
cover. Determine the mass of the dry, empty air meter bowl and cover assembly.
(Mass Method only)
2. Fill the bowl nearly full with water.
3. Clamp the cover on the bowl with the tube extending down into the water. Mark the petcock with the tube attached for future reference.
4. Add water through the petcock having the pipe extension below until all air is forced out the
11 other petcock. Rock the meter slightly until all
air is expelled through the petcock.
5. Wipe off the air meter bowl and cover assembly, and determine the mass of the filled unit (Mass Method only).
6. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed
12 air to cool, and then stabilize the gauge hand at
the proper initial pressure by pumping up or relieving pressure, as needed.
7. Close both petcocks and immediately open the main air valve exhausting air into the bowl. Wait a few seconds until the meter needle stabilizes. The gauge should now read 0 percent. If two or more tests show a consistent variation from 0 percent in the result, change the initial pressure line to compensate for the variation, and use the newly established initial pressure line for subsequent tests.
8. Determine which petcock has the straight tube



Meter cover with petcocks

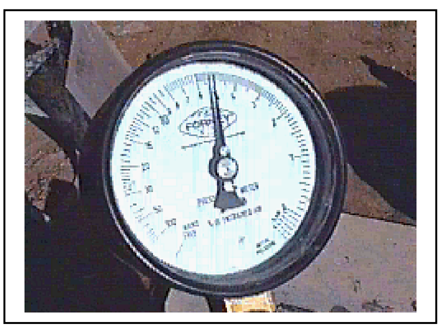
Gauge reading zero

attached to it. Attach the curved tube to external portion of the same petcock.

9. Pump air into the air chamber. Open the
13 petcock with the curved tube attached to it. Open the main air valve for short periods of
14 time until 5 percent of water by mass or volume has been removed from the air meter. Remember to open both petcocks to release the pressure in the bowl and drain the water in the curved tube back into the bowl. To determine the mass of the water to be removed, subtract the mass found in Step 1 from the mass found in Step 5. Multiply this value by 0.05. This is the mass of the water that must be removed. To remove 5 percent by volume, remove water until the external calibration vessel is level full.

- Note: Water can be removed by opening the petcock with the pipe extension and cracking the air valve, or by opening the air valve and cracking the petcock. The method will depend on the design of the air meter but, in either case, a throttling of a valve will be required to limit flow.

Note3: Many air meters are supplied with a calibration vessel(s) of known volume that are used for this purpose. Calibration vessel(s) should be brass, not plastic, and must be protected from crushing or denting. If an external calibration vessel is used, confirm what percentage volume it represents for the air meter being used. Vessels commonly represent 5 percent volume, but they are for specific size meters. This should be confirmed by mass.



Air meter gauge

10. Remove the curved tube. Pump up the air
15 pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and
16 then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.

11. Close both petcocks and immediately open the main air valve exhausting air into the bowl. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ±0.1 percent. If the gauge is outside that range, the meter needs adjustment. The adjustment could involve adjusting the starting point so that the gauge reads 5.0 ±0.1 percent when this

calibration is run, or could involve moving the gauge needle to read 5.0 percent. Any adjustment should comply with the manufacturer's recommendations.

Note 4: Calibration shall be performed at the frequency required by the agency. Record the date of the calibration, the calibration results, and the name of the technician performing the calibration in the logbook kept with each air meter.

12. When the gauge hand reads correctly at 5.0 percent, additional water may be withdrawn in the same manner to check the results at other values such as 10 percent or 15 percent.

13. If an internal calibration vessel is used follow steps 1 thru 8 to set initial reading.
14. Release pressure from the bowl and remove cover. Place the internal calibration vessel into the bowl. This will displace 5 percent of the water in the bowl. (See AASHTO 152 for more information on internal calibration vessels.)
15. Place the cover back on the bowl and add water through the petcock until all the air has been expelled.

17

16. Pump up the air pressure chamber to the initial pressure. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
17. Close both petcocks and immediately open the main air valve exhausting air into the bowl. Wait a few seconds until the meter needle stabilizes. The gauge should now read 5 percent.

Note 5: Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

Procedure Selection

There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 3 in., consolidation is by rodding. When the slump is 1 to 3 in., internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency in order to obtain consistent, comparable results. For slumps less than 1 in., consolidate the sample by internal vibration.

18

Procedure - Rodding

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate 37.5mm (1½ in.) or larger is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

Note 6: Testing shall begin within five minutes of obtaining the sample.

5 Minutes!

2. Dampen the inside of the air meter bowl and place on a firm level surface.

Consolidation

3. Fill the bowl approximately 1/3 full with
19 concrete.

4. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth
20 without hitting the bottom too hard.

5. Tap the sides of the bowl smartly 10 to 15 times with the mallet to close voids and release trapped air.

6. Add the second layer, filling the bowl about 2/3
21 full.

7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. into the bottom layer.

8. Tap the sides of the bowl 10 to 15 times with the mallet.

9. Add the final layer, slightly overfilling the bowl.

10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. into the second layer.

11. Tap the sides of the bowl smartly 10 to 15 times with the mallet.

Strike off

Note 7: The bowl should be slightly over full, about 1/8 in. above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the bowl is
22 under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.

12. Strike off the surface of the concrete and finish it smoothly with a sawing action of the strike-off bar or plate, using great care to leave the bowl just full. The surface should be smooth and free of voids.

13. Clean the top flange of the bowl to ensure a proper seal.

23 14. Moisten the inside of the cover and check to see that both petcocks are open and the main air valve is closed.

15. Clamp the cover on the bowl.

Tapping air meter gauge

16. Inject water through a petcock on the cover until water emerges from the petcock on the other side.
17. Jar and or rock the air meter gently until no air bubbles appear to be coming out of the second petcock. The petcock expelling water should be higher than the petcock where water is being
24 introduced. Return the air meter to a level position and verify that water is present in both petcocks.
18. Close the air bleeder valve and pump air into
25 the air chamber until the needle goes past the initial pressure determined for the gauge. Allow a few seconds for the compressed air to cool.
19. Tap the gauge gently with one hand while slowly opening the air bleeder valve until the needle rests on the initial pressure. Close the air bleeder valve.
20. Close both petcocks.
21. Open the main air valve.
22. Tap the sides of the bowl smartly with the mallet.
23. With the main air valve open, lightly tap the
26 gauge to settle the needle, and then read the air content to the nearest 0.1 percent.
24. Release or close the main air valve.
25. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and bowl with clean water.
26. Open the main air valve to relieve the pressure in the air chamber.

Procedure - Internal Vibration

1. Obtain the sample in accordance with the FOP
27 for WAQTC TM 2. If any aggregate 1½ in. or larger is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.
2. Dampen the inside of the air meter bowl and place on a firm level surface.
3. Fill the bowl approximately half full.
4. Insert the vibrator at three different points. Do not let the vibrator touch the bottom or sides of the bowl.

Note8: Remove the vibrator slowly, so that no air pockets are left in the material.

28 ***Note 9:*** Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

5. Fill the bowl a bit over full.
6. Insert the vibrator as in Step 4. Do not let the vibrator touch the sides of the bowl, and penetrate the first layer approximately 1 in.
7. Return to Step 12 of the rodding procedure and continue.

Report

29

- Results shall be reported on standard forms approved for use by the agency.
- Record the percent of air to the nearest 0.1 percent.
- Some agencies require an aggregate correction factor in order to determine total percent entrained air.

  Total % entrained air =

  Gauge reading – aggregate correction factor from mix design

  (See AASHTO T 152 for more information.)

30

Tips!

- Start within 5 minutes of obtaining sample.
- Use a calibrated air meter.
- Protect the calibration vessel from damage.
- Consolidation technique depends on slump. Rodding and/or vibration may be appropriate for different slumps.

REVIEW QUESTIONS

1. Can the pressure method of determining air content be used on all types of concrete? Explain.

2. What are the required characteristics of the tamping rod used in this test method?

3. What is the specified size of the mallet required for this test method?

4. Describe the calibration process by mass and volume.

5. After rodding each layer, what should be done to the measure before adding another layer of concrete?

6. What tools may be used for striking off the top surface of the concrete following consolidation of the final layer?

7. What must be done if there is a slight deficiency in the quantity of concrete in the measure following consolidation of the final layer?

8. What must be done if there is an excessive amount of concrete in the measure following consolidation of the final layer?

PERFORMANCE EXAM CHECKLIST

AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Representative sample selected?	_____	_____
2. Dampened container filled in three equal layers, slightly overfilling the last layer?	_____	_____
3. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
4. Bottom layer rodded throughout its depth, without forcibly striking the bottom of the container?	_____	_____
5. Middle and top layers rodded, each throughout their depths and penetrating 1 in. into the underlying layer?	_____	_____
6. Sides of the container tapped 10 to 15 times with the mallet after rodding each layer?	_____	_____
7. Concrete struck off level with top of container using the bar or strike-off plate and rim cleaned off?	_____	_____
8. Top flange of base cleaned?	_____	_____
Using a Type B Meter:		
9. Both petcocks open?	_____	_____
10. Air valve closed between air chamber and the bowl?	_____	_____
11. Inside of cover cleaned and moistened before clamping to base?	_____	_____
12. Water injected through petcock until it flows out the other petcock?	_____	_____
13. Water injection into the petcock continued while jarring and or rocking the meter to insure all air is expelled?	_____	_____
14. Air pumped up to just past initial pressure line?	_____	_____
15. A few seconds allowed for the compressed air to stabilize?	_____	_____
16. Gauge adjusted to the initial pressure?	_____	_____
17. Both petcocks closed?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
18. Air valve opened between chamber and bowl?	_____	_____
19. The outside of bowl tapped smartly with the mallet?	_____	_____
20. With the main air valve open, gauge lightly tapped and air percentage read to the nearest 0.1%?	_____	_____
21. Air valve released or closed and then petcocks opened to release pressure before removing the cover?	_____	_____
22. Aggregate correction factor applied if required?	_____	_____
23. Air content recorded to 0.1 percent?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

Examiner Signature _______________________________WAQTC #:_______________

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CONCRETE

METHOD OF MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD

FOP FOR AASHTO T 23

01 Significance

Concrete is specified primarily on the basis of
02 strength. Standard specimens are made and
subsequently tested to determine the acceptability
of concrete. Concrete strength test specimens are
made in accordance with a standard procedure to
produce results that are reliable and tests that can be
reproduced by someone else with the same
concrete, following the same procedures.

Specimens are molded according to standard
procedures and then cured under proper temperature
and moisture conditions. Deviation from the
standard procedures can cause significant
differences in strength results. For example,
specimens improperly cured between 90º and 100°F
03 will develop strength at a different rate than
specimens cured at the specified temperature range
of 60º to 80°F required by this method. Ultimate
04 strength is also affected.

Typical Strength Specimens

This FOP pertains to specimens cast for the purpose of acceptance. Agencies sometimes specify curing practices other than those presented here. (To determine adequacy of protection or when a structure may be placed in service for example.)

Scope

This procedure covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO T 23.

5 **Warning—**Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus and Test Specimens

- Concrete cylinder molds: Conforming to AASHTO M 205 with a length equal to twice the diameter. Standard specimens shall be 6 in. by 12 in. cylinders. Mold diameter must be at least three times maximum aggregate size unless wet sieving is conducted according to FOP for WAQTC TM 2. Agency specifications may allow cylinder molds of 4 in. by 8 in. size when the nominal maximum aggregate size
05 does not exceed 1 in.

06

- Beam molds: Rectangular in shape with ends and sides at right angles to each other. Must be sufficiently rigid to resist warpage. Surfaces must be smooth. Molds shall produce length no more than 1/16” shorter than that required (greater length is allowed). Maximum variation from nominal cross section shall not exceed 1/8 in. Ratio of width to depth may not exceed 1.5; the smaller dimension must be at least 3 times maximum aggregate size. Unless otherwise noted in specifications, beam molds for casting specimens in the field shall result in specimens having width and depth of not less than 6 inches. Specimens shall be cast and hardened with the long axes horizontal.

Apparatus, Cylinders

- Standard tamping rod: 5/8 in. diameter and approximately 24 in. long, having a hemispherical tip for preparing 6 in. x 12 in. cylinders.
- Small tamping rod: 3/8 in. diameter and approximately 12 in. long, having a hemispherical tip for preparing 4 in. x 8 in. cylinders
- Vibrator: At least 7000 vibrations per minute, diameter no more than ¼ the diameter or width of the mold and at least 3 in. longer than the section being vibrated for use with low slump concrete.
- Scoop
- Trowel or Float
- Mallet: With a rubber or rawhide head having a mass of 1.25 ±0.5 lb.
- Rigid base plates and cover plates: metal, glass, or plywood.

- Initial Curing Facilities: Temperature controlled curing box or enclosure capable of maintaining the required range of 60º to 80°F during the entire initial curing period (for concrete with compressive strength of 6000 psi or more, the temperature shall be 68º to 78ºF. As an alternative, sand or earth for initial cylinder protection may be used provided that the required temperature range is maintained and the specimens are not damaged.
- Thermometer: Capable of registering both maximum and minimum temperatures during the initial cure.

07 Procedure – Making Specimens – General

1. Obtain the sample according with the FOP for WAQTC TM 2. Wet Sieving per the FOP for WAQTC TM 2 is required when concrete contains aggregate with nominal maximum size greater than 2 in. for specimens with 6 in. diameter, or greater than 1 in. for specimens with 4 in. diameter. Sieve the sample for 6 in. diameter specimens over the 1½ in. sieve and for 4 in. diameter specimens, over the 1 inch.
2. Remix the sample after transporting to testing location.
3. Begin making specimens within 15 minutes of obtaining the sample.

08

4. Set molds upright on a level rigid base in a location free from vibration and relatively close to where they will be stored.
5. Fill molds in the required number of layers attempting to exactly fill the mold on the final layer. Add or remove concrete prior to completion of consolidation to avoid a deficiency or excess of concrete.

09

6. There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 1 in., consolidation may be by rodding or vibration. When slump is 1 in. or less, consolidate the sample by internal vibration. Agency specifications may dictate when rodding or vibration will be used.

Procedure – Making Cylinders – Rodding

10

1. For the standard 6 in. by 12 in. specimen, fill each mold in three approximately equal layers, moving the scoop or trowel around the perimeter of the mold to evenly distribute the concrete. For the 4 in. by 8 in. specimen, fill the mold in two layers. When filling the final layer, slightly overfill the mold.

Consolidation of concrete in cylinder by rodding

11

2. Consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end. Distribute strokes evenly over the cross section of the concrete. Rod the first layer throughout its depth without forcibly hitting the bottom. For subsequent layers, rod the layer throughout its depth penetrating approximately 1 in. into the underlying layer.

12

3. After rodding each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
4. Strike off the surface of the molds with tamping rod, or straightedge and begin initial curing.

Note 1: Floating or troweling is permitted instead of striking off with rod or straightedge

Vibrating cylinder specimens

13

Procedure – Making Cylinders – Internal Vibration

1. Fill the mold in two layers.

14

2. Insert the vibrator at the required number of different points for each layer (two points for 6 in. diameter cylinders; one point for 4 in. diameter cylinders). When vibrating the bottom

layer, do not let the vibrator touch the bottom or sides of the mold. When vibrating the top layer, the vibrator shall penetrate into the underlying layer approximately 1 in.

3. Remove the vibrator slowly, so that no air
15 pockets are left in the material.

Note 2: Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

4. Strike off the surface of the molds with tamping rod, or straightedge and begin initial curing.

Making a flexural beam, rodding

Procedure – Making Flexural Beams – Rodding

1. Fill the mold in two approximately equal layers
16 with the second layer slightly overfilling the
mold.

2. Consolidate each layer with the tamping rod
17 once for every 2 in^2 using the rounded end. Rod
each layer throughout its depth taking care to not forcibly strike the bottom of the mold when compacting the first layer. Rod the second layer throughout its depth, penetrating approximately 1 in. into the lower layer.

3. After rodding each layer, strike the mold 10 to
18 15 times with the mallet and spade along the
sides and end using a trowel.

4. Strike off to a flat surface using a trowel and begin initial curing.

Making Beams
Internal Vibration

Procedure – Making Flexural Beams – Vibration

19

1. Fill the mold to overflowing in one layer.

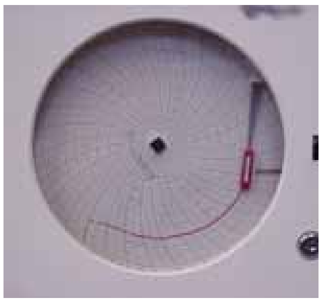
2. Consolidate the concrete by inserting the
vibrator vertically along the centerline at
20 intervals not exceeding 6 in. Take care to not
over vibrate, and withdraw the vibrator slowly
21 to avoid large voids. Do not contact the bottom

or sides of the mold with the vibrator.

3. After vibrating, strike the mold 10 to 15 times with the mallet.
4. Strike off to a flat surface using a trowel and begin initial curing.

22

Procedure – Initial Curing



Recording Thermometer

- When moving cylinder specimens made with single use molds, support the bottom of the mold with trowel, hand or other device.

23

- For initial curing of cylinders, there are two methods, use of which depends on the agency. In both methods, the curing place must be firm, within ¼ in. of a level surface, and free from vibrations or other disturbances.

24

- Maintain initial curing temperature of 60º to 80°F or 68º to 78°F for concrete with strength of 6000 psi or more.
- Prevent loss of moisture.

Temperature Controlled Cure Box

Method 1 – Initial cure in a temperature controlled chest-type curing box

25

1. Finish the cylinder using the tamping rod, straightedge, float or trowel. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).

26

2. Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides).
3. Place the lid on the mold to prevent moisture loss.
4. Mark the necessary identification data on the cylinder mold and lid.

Thermostatically Controlled Cure Box

Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder

27

Note 3: This procedure may not be the preferred method of initial curing due to problems in maintaining the required range of temperature.

Placing cover plate

1. Move the cylinder with excess concrete to the initial curing location.
2. Mark the necessary identification data on the cylinder mold and lid.
3. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 2 in. of the top.

28

4. Finish the cylinder using the tamping rod, straightedge, float or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 1/8 in.
5. If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period or place the lid on the mold to prevent moisture loss.

29 Procedure – Transporting Specimens

Specimen identification

After 24 to 48 hours of initial curing, the specimens will be transported to the laboratory for final cure. Specimen identity will be noted along with the date and time the specimen was made and the maximum and minimum temperatures registered during the initial cure.

30

- While in transport, specimens shall be protected from jarring, extreme changes in temperature, freezing, or moisture loss.
- Cylinders shall be secured so that the axis is vertical.
- Transportation time shall not exceed 4 hours.

Final Curing

- Upon receiving cylinders at the laboratory,
31 remove the cylinder from the mold and apply the appropriate identification.
- For all specimens (cylinders or beams) final curing must be started within 30 minutes of mold removal. Temperature shall be maintained at $73^{\circ} \pm 3^{\circ}$ F Free moisture must be present on the surfaces of the specimens during the entire curing period. Curing may be accomplished in a moist room or water tank conforming to M 201.
- For cylinders, during the final 3 hours prior to testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested.
- Final curing of beams must include immersing in lime-saturated water for at least 20 hours prior to testing.

32

Report

- Report on standard agency forms.
- Placement information for identification of project, element(s) represented, etc.
- Date molded & Time molded.
- Test ages.
- Slump, Air Content & density.
- Temperature (concrete, initial cure max. & min., and ambient).
- Method of initial curing.

Other information as required by agency such as concrete supplier, truck number, invoice number, water added, etc.

Tips!

- Start within 15 minutes of obtaining sample. 33
- Use hand, for tapping single-use, light-gauge molds.
- Consolidation technique depends on the slump. Rodding and/or vibration may be appropriate for different slumps.
- Protect specimens from damage during transport and keep cylinders vertical.

REVIEW QUESTIONS

1. AASHTO T 23 gives standardized procedures for __________, ____________, and ______________ of test specimens.

2. Describe two methods for initially curing test specimens.

3. When consolidating a flexural strength test specimen by rodding, rod one stroke for each ______ of top surface area.

4. Describe the process for making flexural beam specimens using internal vibration. What precautions must be taken?

5. During transportation, what must be done to protect test specimens?

PERFORMANCE EXAM CHECKLIST

MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD FOP FOR AASHTO T 23

Participant Name ______________________________ Exam Date ______________

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Molds placed on a level, rigid, horizontal surface free of vibration?	_____	_____
2. Representative sample selected?	_____	_____
3. Making of specimens begun within 15 minutes of sampling?	_____	_____
4. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
5. Mold filled in equal layers, attempting to exactly fill the mold on the last layer?	_____	_____
6. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
7. Bottom layer rodded throughout its depth?	_____	_____
8. Subsequent layer(s) rodded throughout depth penetrating 1 in. into the underlying layer?	_____	_____
9. Sides of the mold tapped 10-15 times after rodding each layer?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
10. Concrete struck off with tamping rod or, if necessary, finished with a trowel or float?	_____	_____
11. Specimens covered with non-absorptive, non-reactive cap or plate?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

____

____

____

____

Examiner Signature ______________________________WAQTC #:______________